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COMMERCIAL AIRPORT OPERATIONS AND COMMUNITY NOISE CRITERIA.(U)

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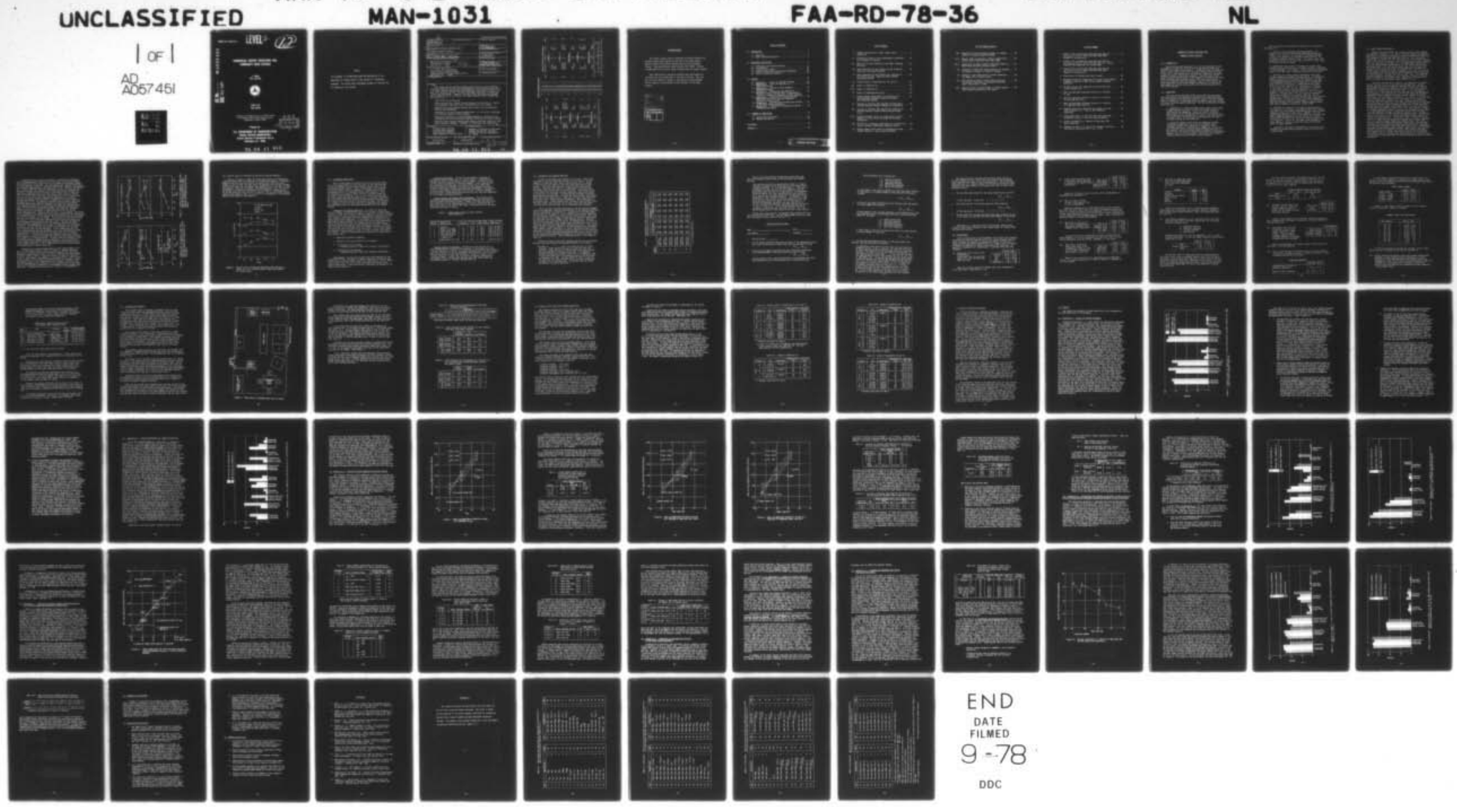

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COMMERCIAL AIRPORT OPERATIONS AND COMMUNITY NOISE CRITERIA

J.E. MABRY
B.M.S. SULLIVAN

MARCH 1978
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
(18) FAA-RD (19) 78-36		

4. Title and Subtitle	5. Report Date
(6) Commercial Airport Operations and Community Noise Criteria.	(11) March 1978
	6. Performing Organization Code
	8. Performing Organization Report No. (14) MAN-1031
7. Author(s) (10) J. E. Mabry ~~and~~ B. M. Sullivan	
9. Performing Organization Name and Address (S.) MAN-Acoustics and Noise, Inc. 2105 North 45th Street Seattle, WA 98103 (12) 77p.	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. (15) DOT-FA77WAI-723 new
12. Sponsoring Agency Name and Address U. S. Dept. of Transportation Federal Aviation Administration Systems Research and Development Service Washington, DC 20590	13. Type of Report and Period Covered (9) Final Report,
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This study program involved response of 48 persons to seven different simulated commercial airport noise environments. Each exposure period was of 1-1/2 hours duration and subjects experienced and rated eight of these 1-1/2 hour noise exposure periods. The test environment simulated a conventional living room environment. Number of aircraft noise intrusions per exposure period ranged from 6 to 18 flyovers and indoor Leq(dBA) levels ranged from 38.9 to 52.1 dB.

Some of the conclusions are:

- Noise exposure from a 'new' aircraft fleet mix (circa 1980) is clearly more acceptable than that from an 'old' fleet mix (circa 1965).
- Commonly used noise exposure methods such as NEF, Leq, and mean peak dBA are level dependent.
- Depending on the noise exposure method used, 2.5 to 4.0 dB is perceived as a reliable change in noise exposure.
- Predictive capability of a noise exposure method is a function of the engineering calculation procedure employed to weight the acoustic energy.
- Mean peak level exposure methods have greater predictive capability than energy summation methods. Leq(dBA) is a relatively poor predictor.

17. Key Words	18. Distribution Statement
Aircraft Noise Criteria Aircraft Noise Annoyance Noise Exposure Methods Human Response to Aircraft Noise	Document is available to the public through the National Technical Information Service, Springfield, VA 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	76	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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METRIC CONVERSION FACTORS

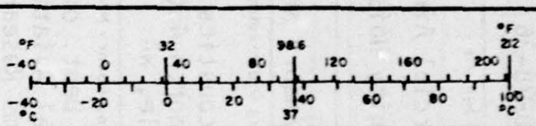
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ACKNOWLEDGMENTS

The flyover signals used to represent the seven different commercial airport noise conditions are part of the NASA Langley Research Center Noise Effects Branch aircraft noise signature library. They were obtained under Contract NAS1-14404. We want to thank NASA for the use of these listening quality flyover signals.

Other MAN-Acoustics and Noise personnel who contributed significantly to this program were J. Ott and R. Shields. Also, we want to thank Thomas H. Higgins of FAA Research and Development for his technical contributions to and interest in this study program.

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COMMERCIAL AIRPORT OPERATIONS AND COMMUNITY NOISE CRITERIA

1.0 INTRODUCTION

Noise from aircraft operations is a serious impediment to the advancement of commercial aviation and to the orderly planning of community activities around airports. Although a number of commercial airport noise studies utilizing a variety of methods have been completed, due to the complexity of the problem, controversy concerning commercial airport noise effects remains. The objectives of this program involve identification of key elements in airport noise evaluation technology and providing results that could contribute to decisions concerning these key elements. The following section provides objectives of this study program followed by a discussion of some commercial airport noise results which illustrate some of the identified problems.

1.1 Objectives

There are seven objectives which are divided into two groups. One group involves two operational differences or comparisons which lead to different noise exposures around an airport, while the second group of objectives is concerned with more general questions related to airport noise evaluation technology. The two operationally oriented objectives are:

1. Determine if a takeoff procedure which reduces noise levels at approximately 4.5 to 8.0 n. miles from brake release is perceived by the community. Since this takeoff procedure applies only to 727-100 and 727-200 aircraft, but persons in their homes are also responding to flyovers from other aircraft at higher levels, it may be that noise reductions for these selected aircraft are not effective.

2. Determine whether-or-not there are community response differences between an airport noise environment which represents typical 1965 operations as opposed to 1975 or post-1975 operations. Evaluations of commercial airport noise environments, utilizing energy summation approaches such as NEF and Ldn, indicate that airport noise exposure is decreasing. However, there is little evidence that persons living around airports perceive this decrease in noise exposure.

The five objectives concerned with airport noise evaluation technology are:

3. Scaling of noise exposure evaluation methods. For example, for the widely used energy summation methods such as NEF or Ldn, does a 2, 3, 5, or 6 dB increase represent a doubling of annoyance to multiple flyover events? Are the energy summation methods linear? For example, does noise annoyance increase at the same rate in the 30 to 35 NEF range as in the 40 to 45 NEF range?

4. Determining the increase or decrease in airport noise exposure which is perceived as a reliable increase or decrease in noise annoyance. For example, if noise exposure is decreased from 35 to 32 NEF, does a community perceive this decrease?

5. Selection of a noise exposure methodology which best reflects community response to airport noise. A hypothetical example can be used to illustrate this objective. It may be that annoyance to airport noise is primarily associated with remembered response to the loudest group of flyovers which occur on any given day. Assume that an additional group of aircraft operations is introduced at a minimum of 5 dB below the level of this loudest group of flyovers. If the loudest-group-of-flyovers hypothesis is valid, annoyance response from the community will remain unchanged. However, if the mean peak level, utilizing an engineering calculation procedure such as dBA or PNdB, was used to measure noise exposure, it would indicate that noise exposure had decreased. On the other hand, if an energy summation approach such as Ldn were to be employed, it would indicate that noise exposure had increased. Neither approach would best reflect community response to airport noise.

6. Determine the validity of the equal energy hypothesis. This objective is related to the previous one which involves selection of a noise exposure methodology which best reflects community response to airport noise. However, since the equal energy hypothesis is the cornerstone of the widely used energy summation approaches such as Ldn and NEF, results specifically directed to the validity of the hypothesis are to be obtained. Simply put, the equal energy hypothesis is: equal amounts of acoustic energy over equal time periods result in equal response.

7. Determine a threshold of acceptability for airport noise exposure for persons during evening leisure time activities in their homes.

1.2 Some Illustrative Results

Results using two methods for assessing airport noise exposure are provided in Figures 1., 2., and 3. Data for takeoff and approach operations are presented individually and the two methods of assessing noise exposure are mean peak dBA levels and Leq. The time period represented is 8:00 A.M. to 3:00 P.M. for all of the six years investigated. The results are based on state-of-the-art noise-thrust-distance plots but corrected on the basis of a 1976 measurement program (Ref. 1). Fleet mix and operations characteristic of the various years investigated were used. Since for any particular day, aircraft operations producing the noise at the points investigated would be either all takeoffs or all landings, results in Figures 1., 2., and 3. are based on the premise that but one type of operation would take place during the time period of interest (8:00 A.M. to 3:00 P.M.). This approach actually represents the manner in which persons residing in the area would be exposed to the flyover noise. Recordings from two of the points are used for the present study (Figures 1. & 3.).

Turning to the results of Figure 1. as a means of illustrating some of the aims of this study, from 1963 through 1969, the mean outdoor peak dBA level for takeoffs remained relatively constant at approximately 97 dBA but dropped to 93.5 dBA in 1972 with a further decrease to slightly under 92 dBA for 1976. Is the mean takeoff decrease of 3.5 dBA from 1969 to 1972 perceived as an improvement for those exposed to the airport noise and does the mean peak dBA method adequately reflect community response to these changes in airport operations? For the results of Figures 1., 2., and 3., on the average over a calendar year, takeoffs occur two-thirds of the time with landings occurring one-third of the time. Remaining with the mean peak dBA method for measuring noise exposure, but based on the approach operations, approach noise increases by more than 4.5 dBA from 1963 through 1969, with a mean of 96.6 dBA in 1969. As with the decrease for takeoff noise between 1969 and 1972 of 3.5 dBA, possibly leading to decreased annoyance, there is the question of whether-or-not there is a corresponding increase in community aircraft noise annoyance resulting from this 4.5 dBA increase for approach noise. In addition, there is the possibility of interaction effects between response to takeoff and approach noise. In the early 1960's, approach noise was clearly at lower levels than takeoff noise while at present, approach noise is, on the average, higher than takeoff noise at this point directly under the takeoff and approach flight path. Over and above questions concerning perceived increases and decreases in annoyance, as a function of changes in mean peak dBA levels and the corresponding magnitude of community annoyance changes, these results also provide evidence relative to selection of source noise control strategies. That approach noise is louder than take-off noise from 1972 onwards could easily lead to the conclusion that reduction of aircraft noise at the source is more important for approach operations than for takeoff operations.

Remaining with the results of Figure 1., which can be characterized as representative of noise levels relatively close to the airport and directly under the flight path, the Leq method for measuring changes in noise exposure is examined. For both takeoff and approach operations, Leq increases approximately 3 dBA from 1963 to 1966. However, the approach Leq is some 10 dBA less than the takeoff Leq so, for this time period, it would be concluded that takeoff noise almost completely determines the Leq level. Approach noise continues to increase by some 2.5 dBA from 1966 to 1969 and then levels off from 1969 to 1976, with Leq ranging from 74.2 to 74.9 over that eight year period while for this same time period, the takeoff Leq has decreased by approximately 2.5 dBA and levelled off between 1972 and 1976. A comparison of results based on the mean dBA vs. the Leq methods of measuring noise exposure shows that different conclusions would be obtained as a function of the method used. During and after 1972, it would be concluded that approach noise significantly impacts the community based on the mean peak dBA method. However, using the Leq method of measuring noise exposure, approach noise would not be considered a significant factor for any of the yearly determinations. Based on the fact that, on the average, two-thirds of the operations are takeoffs and one-third are approaches for the measurement point of Figure 1., an "average" Leq (2/3 takeoffs and 1/3 approaches over the time period) was calculated. The results are plotted as "Δ——Δ" in Figure 1. This is the usual approach for calculating an energy summation exposure method such as Leq, Ldn or NEF. The Leq plot based on both takeoffs and approaches tracks the separate takeoff Leq almost perfectly. The combined Leq is, at most, 1.8 dBA less than the takeoff Leq due to the fact that but two-thirds of the takeoffs are utilized along with one-third of the approaches. From a comparative point of view, approach noise does not influence Leq in that differences between various years (different operations) are the same, with or without approach noise. Utilizing only the Leq method for measuring airport noise impact, it would be concluded that approach noise does not impact the community in a negative manner. In fact, under the assumption that Leq validly reflects community noise annoyance, a logical conclusion is that noise from approach operations decreases noise impact since it lowers takeoff Leq's by 1.5 to 1.8 dBA due to using the average number of takeoffs based on yearly operations.

Results for a sideline measurement position (approximately 0.37 n. miles from centerline) are given in Figure 2. Whether mean peak dBA or Leq is used to track noise exposure, takeoff noise levels predominate in that takeoff noise is at least 12 dBA greater than approach noise for identical years. Questions similar to those for results of Figure 1. are raised. For example, is the approximately 3 dBA increase of the takeoff Leq from 1963 to 1966 perceived as an increase in noise annoyance? Also, is the 3 dBA decrease for takeoff Leq between 1969 and 1972 experienced as a decrease in noise annoyance and is the magnitude of this decrease comparable to the presumed increase between 1963 and 1966? Is approach noise actually of little or no consequence at

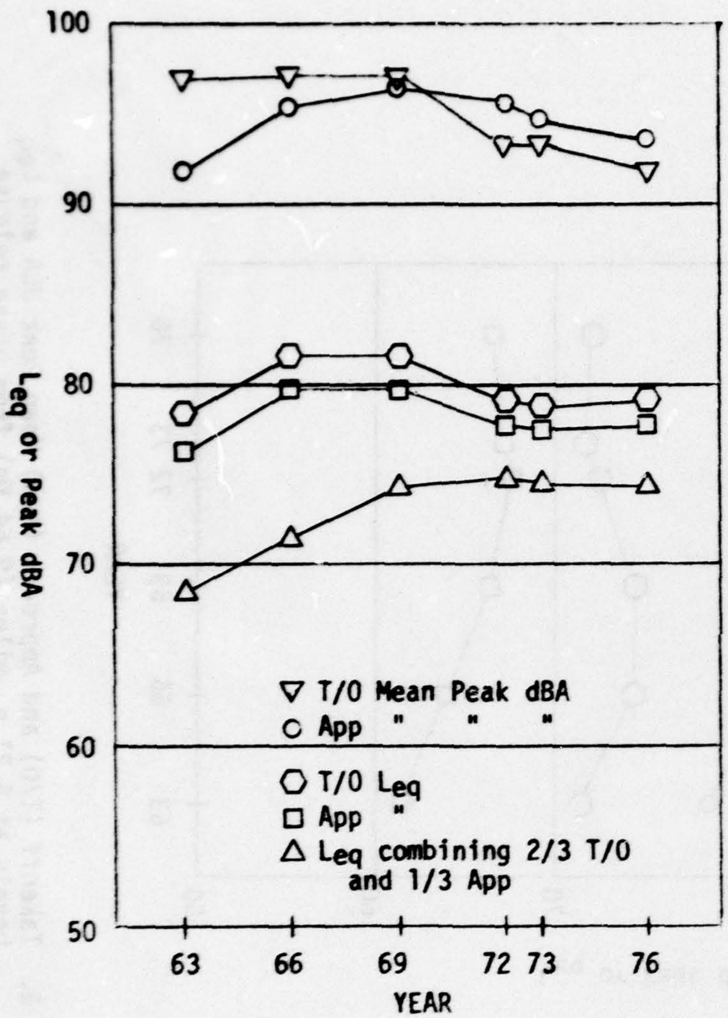


Figure 1. Takeoff (T/O) and Approach (App) Mean Peak dBA and L_{eq} Levels at 3.04 n. miles (5.63 Km) from brake release for various years.

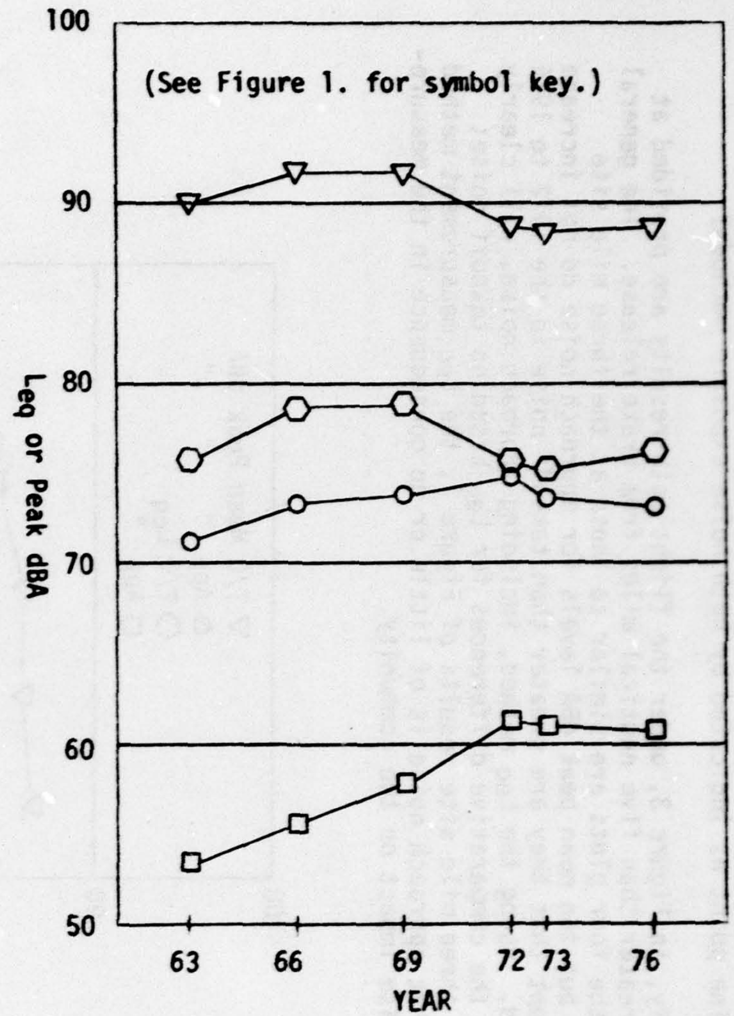


Figure 2. Takeoff (T/O) and Approach (App) Mean Peak dBA and L_{eq} Levels at 2.80 n. miles (5.18 Km) and .37 n. miles (.68 Km) from centerline for various years.

this sideline point as indicated by both noise exposure methods?

Finally, in Figure 3, under the flight path results are provided at slightly greater than five nautical miles from brake release. The general shapes of the four plots are similar to those at the three mile site (Figure 1) but the mean peak dBA levels for approach noise do not increase to the extent that they are greater than takeoff noise in the 1972 to 1976 time period. Using the L_{eq} method, including approach noise, will clearly not change the comparative differences for L_{eq} based on takeoff noise; as for the three mile site results of Figure 1, the L_{eq} measurement method suggests that approach noise is of little or no consequence in the measurement of noise impact on the community.

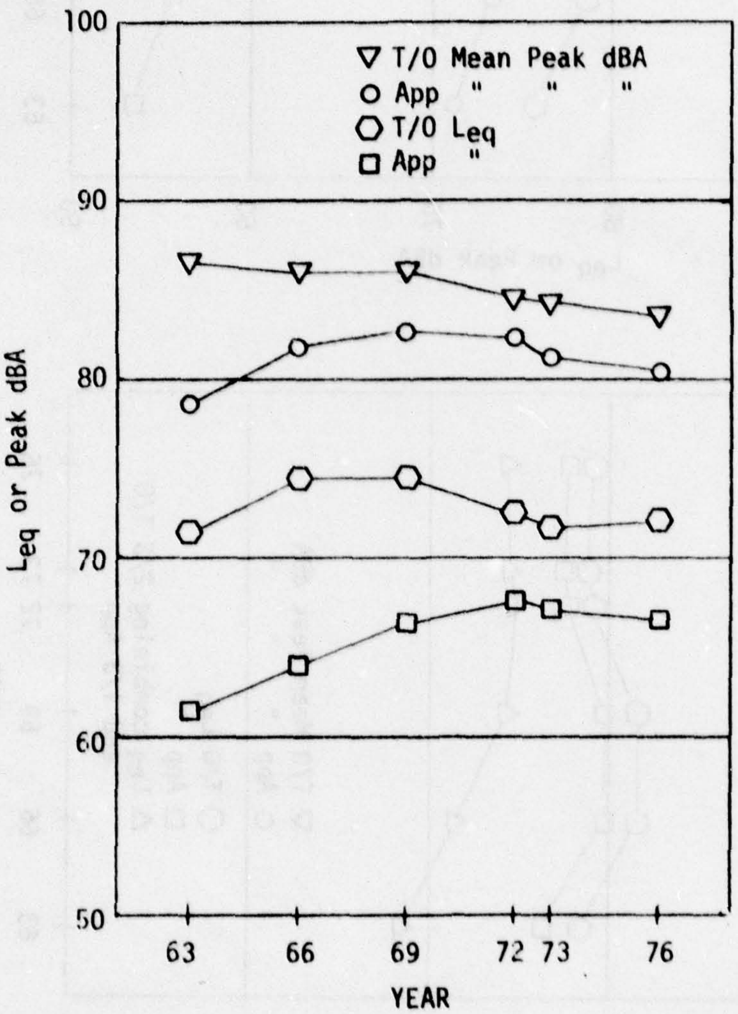


Figure 3. Takeoff (T/O) and Approach (App) Mean Peak dBA and L_{eq} Levels at 5.21 n. miles (9.64 Km) from brake release for various years.

2.0 EXPERIMENT DESCRIPTION

Basic to the method for obtaining results that could contribute to an understanding of the seven aims, is the idea that the testing environment and conditions should simulate actual living situations around airports. Thusly, persons were to be exposed to various airport noise environments in a manner that could be representative of an in-the-home airport noise exposure. Since the evening period around airports results in greater annoyance to airport noise (References 2 and 3), this time period was used. All noise conditions were presented during a 1-1/2 hour time period and from 7:00 to 8:30 P.M. with the aim of simulating one-half of the 7:00 to 10:00 P.M. period of an evening at home. The following is a summary of the five areas involved in completing the program. Detailed descriptions of the methods employed follows the summary section.

Procedures and Response Measures: As a means of obtaining results relevant to the multiple aims of this program, subjects were exposed to seven airport noise conditions, each of 1-1/2 hours duration. Since one of the aims involved scaling of methods for measuring airport noise exposure, magnitude estimation judgments were obtained to all seven airport noise conditions. As an adjunct to utilization of the magnitude estimation method to rate multiple noise events experienced over a fixed period of time, all subjects were first exposed to a "standard" noise condition for three consecutive sessions. Subjects then utilized their experience with this standard condition as a base for rating the various airport noise conditions. In all, each subject was expected to participate in eight 1-1/2 hour sessions for a total of 12 hours. The main response measures obtained at the completion of each session were:

1. Magnitude estimation judgments.

2. Whether-or-not noise condition is acceptable.

3. Interference with listening
   Annoyance rating if there were listening interference.

4. Interference with speaking
   Annoyance rating if there were speaking interference.

Participants: So that participants were representative of the population at large, they were, as much as possible, selected so that a wide range of socio-economic levels was represented. In all, forty-eight persons took part in the study with males and females being equally represented. Eight persons were simultaneously exposed to the various noise condtions.

Listening Environment: The testing environment is designed to represent a typical living room in a smaller home or apartment with kitchen facilities within the main testing chamber. Toilet facilities for both sexes are adjacent to the main chamber. Since eight persons were exposed at the same time to various airport noise conditions, possible interactions between room acoustics and presentation levels at each of the eight listening positions were determined. Presentation of the aircraft flyover noise was via six direct radiation speakers with four means of controlling amplification so that level was comparable at the various listening positions.

Flyover Signals and Airport Noise Conditions: The flyovers were recorded at two locations directly under the flight path and south of Seattle-Tacoma International Airport. Number of flights and noise level were chosen so as to be representative of realistic conditions which would contribute to the aims of the study. Characteristics of the seven conditions are given in Table I.

Table I. Summary Descriptions of Seven Airport Noise Conditions

Condition Number	Qualitative Description	No. of Flyovers	Condition Leq	Mean Peak dBA Levels	Range of Peak dBA Levels
1	Standard	12	45.5	62.4	54.7 to 69.6
2	Stand. plus 6dBA	12	51.4	68.4	60.7 to 75.6
3	Stand. minus 6dBA	12	39.9	56.4	48.7 to 63.6
4	"Old" Noise Envir.	6	52.1	68.8	62.9 to 71.7
5	"New" Noise Envir.	18	51.9	64.4	59.1 to 70.9
6	In route climb (IRC) T/O	12	41.6	57.0	48.2 to 60.5
7	Deep Thrust (DT) T/O	12	38.9	54.3	48.8 to 60.5

Physical Acoustical Analyses: The basis for the analyses of all noise conditions was 1/3-octave band analyses in accordance with specifications detailed in FAR-36. As a means of measuring total noise exposure some 109 variations on various approaches were examined. The 1/3-octave results were based on real time analyses of flyovers as heard in the listening chamber. Engineering calculation procedures emphasized in development of the various noise measures were dBA, $PNdB_T$ (PNdB tone corrected according to FAR-36), and dBH (Ref. 4).

2.1 Procedures and Response Measures

A total of 48 people was exposed to the seven airport noise conditions, with each condition lasting for 1-1/2 hours. The 48 subjects, of whom half were female, were divided into six groups of four men and four women so that each group consisted of eight persons. Each group was required to come to eight experimental sessions. Sessions took place in a comfortable living-room type environment and occurred from 7:00 to 8:30 P.M. Each subject chose a seat within the test room, and was requested to spend the session as he would in his own home. A television was provided, along with magazines and playing cards. Conversations were allowed, and subjects could leave their seats freely. There was a kitchen area within the test room, with a coffee pot and refrigerator. Rest rooms were in an adjacent area. Though subjects were allowed to move around freely, they were asked, when sitting, to sit only in the seat they chose initially and to use that seat for all remaining seven sessions.

The first three sessions took place on the evenings of a Monday, Tuesday and Wednesday, and were presentations of the standard condition, which is designated as condition #1. Subjects were told that these sessions were to be rated 10. The following five sessions took place on the evenings of Monday to Friday of the following week. The first of these sessions was a repeat of condition #1, but the subjects were not told that this was a repeat of the standard session. The next two sessions were conditions #2 and #3, in varying order. Of the six groups of eight people, three groups heard conditions #4 and #5 in the final two sessions, and three heard conditions #6 and #7. This experimental design is shown in Table II. As each condition was recorded on three magnetic tapes, labelled A, B, and C, the playing order of the tapes was varied for the standard session (condition #1) and conditions #2 and #3, as these conditions contained the same flyover events; the aim of changing tape presentation orders was to reduce the possibility of any memorizing effects. Tape presentation order is also shown in Table II.

Before the start of the first standard session, the experimental observer read the following introductory remarks to the subjects:

> "My name is ____________ and I'll be with you for all eight sessions. Since we will want you to occupy the same seat during all eight sessions, we should work seating out tonight. You may spend the 1-1/2 hours as you like -- by reading, knitting, conversing, watching television, or engaging in some leisure time games (we'll have playing cards at the table and a cribbage set or two). How you spend the time is up to you. You may leave your seat but when you do sit down, we want you to always sit in the same seat. I hope that this will help and that we can select seats now."

Table II. Presentation order of seven experimental conditions to six groups of subjects.

GROUP		SESSION #							
		First Week			Second Week				
		1	2	3	4	5	6	7	8
I	Condition	STD	STD	STD	#1*	#2	#3	#6	#7
	Tape Order	ACB	CBA	ABC	BCA	CAB	BAC	ABC	ABC
II	Condition	STD	STD	STD	#1	#3	#2	#6	#7
	Tape Order	CAB	BAC	ACB	CBA	ABC	BCA	ABC	ABC
III	Condition	STD	STD	STD	#1	#2	#3	#7	#6
	Tape Order	ABC	BCA	CAB	BAC	ACB	CBA	ABC	ABC
IV	Condition	STD	STD	STD	#1	#3	#2	#4	#5
	Tape Order	ACB	CBA	ABC	BCA	CAB	BAC	ABC	ABC
V	Condition	STD	STD	STD	#1	#2	#3	#5	#4
	Tape Order	CAB	ACB	BAC	CBA	ABC	BCA	ABC	ABC
VI	Condition	STD	STD	STD	#1	#3	#2	#4	#5
	Tape Order	ABC	BCA	CAB	BCA	ACB	CBA	ABC	ABC

* #1 is Standard condition.

Then he read the following instructions, which were also read to the subjects before each of the succeeding two standard sessions:

"The condition you will be experiencing tonight is ("again"- inserted for second and third evenings of the standard) the standard condition. It is given the number 10. The idea is to remember as best that you can this standard condition which will occur over the 1-1/2 hour period. For conditions occurring during 1-1/2 hour periods during later sessions, we'll ask you to rate these conditions in proportion to your evaluation of this standard condition. For example, if you think that a later session is twice as annoying as the standard you would assign the number "20" to that session. If one-half as annoying, you would rate that session as "5". If just slightly more annoying, you might rate the session as "11" or "12" and so on. To all of the evaluations you'll be making, we want your own individual opinion. We'll be obtaining some kind of evaluations at the end of each session."

At the end of each session, the subjects were asked to fill out the following evaluation form. For the three standard sessions, they were instructed to give a Session Rating of 10.

SESSION EVALUATION FORM I

NAME ____________________ DATE ____________

SEAT NUMBER ____________ SESSION ____________

1. Session Rating ____________.

2. If the sounds experienced here were to occur in the same manner during your usual leisure hours at home, would they be acceptable to you?

   YES ____ NO ____

3. Did any of the sounds interfere with your listening to television or to another member of the group while they were talking?

   YES ____ NO ____

   If your answer is YES, use the following to rate annoyance you could have experienced due to interference with a listening activity.

The interference with listening was:

___A. Almost Intolerable
___B. Very Much Annoying
___C. Moderately Annoying
___D. Very Little Annoyance
___E. Not At All Annoying

If your answer is NO, did any sounds occur while you were listening to television or to another member of the group while they were talking?

YES____ NO____

4. Did any of the sounds interfere with your talking (your own speech) to another member of the group?

YES____ NO____

If your answer is YES, use the following to rate annoyance you could have experienced due to interference with your talking to another member of the group.

___A. Almost Intolerable
___B. Very Much Annoying
___C. Moderately Annoying
___D. Very Little Annoyance
___E. Not At All Annoying

If your answer is NO, did any sounds occur while you were talking to another member of the group?

YES____ NO____

For the five experimental sessions in the second week, the observer read the following instructions:

"As mentioned on the three occasions that you experienced the standard session, it has a rating of "10" and that you would be using your evaluation of the standard session to rate later sessions. The idea is to rate this session in proportion to the standard session using numbers. If this session has about the same annoyance value as the standard session you will give it the number "10". If the session you have just experienced is twice as annoying for you as the standard session, you will rate it as "20" on your answer sheet. If 1/2 as annoying as the standard session you will rate it as "5". If about 1/4 as annoying you would rate this session as 2.5. If just slightly more annoying than the standard session you might assign the present session a rating of "11" or "12" and so on. As with other evaluations, we want only your personal evaluations of the total sound experience for this session."

The same evaluation form was used following these sessions as for the standard session. After the final sessions, the following three questions were added to the evaluation form. The aim of these three questions was to have a means of examining the possibility that annoyance with other members of the group could lead to higher noise annoyance ratings.

5. Did you find other persons in the group interesting to be with?

YES_____ NO_____

If YES, how many? Circle one: 1 2 3 4 5 6 7

6. Were there persons in the group whom you found annoying?

YES_____ NO_____

If YES, how many? Circle one: 1 2 3 4 5 6 7

7. Do you expect the sessions would have been more pleasant for you if you could have selected the other seven members of the group?

YES_____ NO_____

Additionally, at the end of this final session, subjects were asked to report their estimate of the average number of flyovers they had heard each evening.

2.2 Participants

Prior to taking part in the experiment, each subject was examined audiologically and was required to fill in a noise-oriented questionnaire, as there was interest in determining whether the group as a whole could be considered representative of a general adult population. Following are summaries of results from some of the questions. The question or characteristic investigated is provided along with the responses.

(1) How do you like living in this neighborhood? Do you rate it as an excellent, good, fair, poor, or very poor place to live?

	Female	Male
Excellent	45.8%	33.3%
Good	41.7%	37.5%
Fair	8.3%	20.8%
Poor	4.2%	8.3%
Very Poor	0%	0%

Thus, 71% of males and 88% of females rate their neighborhood as an excellent or good place to live.

(2) Do you like many things, just a few things, hardly anything or nothing at all about living around here?

	Female	Male
Many things	83.3%	62.5%
A few things	12.5%	29.2%
Hardly anything	0%	8.3%
Nothing at all	4.2%	0%

Generally, the group is positive about their neighborhood, in concordance with paragraph (1).

(3) What are some of things you don't like about living in your neighborhood?

When the responses to this open-ended question were examined, it was found that 45.8% males and 33.3% females spontaneously mentioned noise as a factor disliked in the neighborhood. Of the 24 males questioned, seven mentioned traffic noise, one airport noise, one boats and trains, three noise from neighbors and one dogs; seven of the females mentioned traffic noise and two airplanes.

(4) How noisy or quiet do you think this neighborhood is? Very noisy, somewhat noisy, somewhat quiet, very quiet?

	Females	Males
Very noisy	4.2%	8.3%
Somewhat noisy	25.0%	20.8%
Somewhat quiet	37.5%	54.2%
Very quiet	29.2%	12.5%
No answer	4.2%	4.2%

The perception of the neighborhood as quiet predominates for these subjects, in similar proportions for both sexes, 66.7% of both females and males using the ratings "somewhat" or "very quiet."

(5) When you're inside your house, does noise in the neighborhood bother or annoy you very much, moderately, very little or not at all?

	Female	Male
Very much	4.2%	8.3%
Moderately	12.5%	25.0%
Very little	54.2%	37.5%
Not at all	29.2%	29.2%

Males in this group tend to be more annoyed by neighborhood noise, 33.3% reporting very much or moderate annoyance, compared to 16.7% of females.

(6) When you're inside your house, which is the MOST bothersome noise from the neighborhood you hear?

Category	Female	Male
Traffic	50.0%	50.0%
Neighbors	20.8%	20.8%
Planes and helicopters	16.7%	8.3%
Dogs and cats	12.5%	8.3%
Other	16.7%	20.8%
Nothing	4.2%	8.3%

Traffic noise comprises the most often mentioned category of bothersome noise, with noises from neighbors second in frequency. Some subjects gave multiple responses, hence the percentage totals are over 100.

(7) Each subject responded to a ten item noise sensitivity test, which has been used in previous studies (Ref. 6), using the following category scale:

a. extremely annoying
b. moderately annoying
c. slightly annoying
d. not annoying

Answers were scored as 0 (for not annoying), 1, 2, or 3 (for extremely annoying). For the ten items, therefore, scores could range from 0 to 30.

	Females	Males
Mean	17.9	19.5
Standard Deviation	4.04	5.24
Range	9 - 26	9 - 29

Earlier work (Ref. 5) shows mean scores at approximately 15. The means in this study are somewhat higher, which could be due to the present subjects being more sensitive to noise than the general population, and thus being more interested in taking part in a noise study, or because increased publicity about noise-related questions has perhaps made people more willing to rate themselves as being noise sensitive.

For data analysis purposes, the subjects were split up into two halves, one half experiencing experimental conditions #1, #2, #3, #4, and #5, and the other conditions #1, #2, #3, #6, and #7. To ensure no bias in noise sensitivity between these two halves, scores on this test were compared.

	Subjects hearing #1 - #5	Subjects hearing #1 - #3, #6, #7
Mean	18.8	18.7
Standard Deviation	4.05	5.31
Range	10 - 27	9 - 29

(8) Compared to other people, are you more aware of noise than others, about the same as others, or less aware of noise than other persons?

	Females	Males
More aware	37.5%	37.5%
Same	58.3%	45.8%
Less aware	4.2%	16.7%

Clearly, these subjects do not consider themselves unaware of noise compared with other people, though most consider themselves of average sensitivity.

(9) Some people have said that "pollution is one of the biggest problems of modern times." Would you agree strongly, agree somewhat, disagree somewhat, or disagree strongly with this statement?

	Females	Males
Agree strongly	58.3%	54.2%
Agree somewhat	37.5%	45.8%
Disagree somewhat	4.2%	0%
Disagree strongly	0%	0%

Apart from one female, all subjects agree to some extent that pollution is a serious problem.

(10) This section provides information relative to socio-economic levels, such as number of years of schooling completed, income occupation and age of participants.

SCHOOLING COMPLETED

	Females	Males
Average number of years of schooling completed	13.6	14.4
Range of years completed	10 - 20	8 - 21

A wide range of educational experience is represented, with a number of college graduates in both male and female groups. Some subjects were still completing graduate and post-graduate study during the period of the experiment.

YEARLY FAMILY INCOME

	Female	Male
Under $5,000	12.5%	12.5%
5,000 - 9,999	48.8%	41.7%
10,000 - 14,999	16.7%	16.7%
15,000 - 19,999	4.2%	12.5%
20,000 or more	20.8%	16.7%

There is a wide range of yearly incomes, with the largest number in the $5,000 - 9,999 p.a. bracket.

SUMMARY OF AGES FOR PARTICIPANTS

Age Category	Female	Male
20 - 24	4.2%	4.2%
25 - 29	25.0%	50.0%
30 - 34	4.2%	12.5%
35 - 39	12.5%	12.5%
40 - 44	12.5%	8.3%
45 - 49	12.5%	8.3%
50 - 54	8.3%	4.2%
55 - 59	8.3%	0%
60 - 64	0%	0%
65 - 69	12.5%	0%

As wide an age range as possible was included in this study. Median age for the females was 42 and for the males 29.

(11) Results from the attitudinal items have greater meaning when compared to those obtained from the population at large. Responses to these same questions were gathered from adult respondents living in 659 randomly selected households (Ref. 6), intended to be representative of the general population. Results from that study are here compared with those obtained in the present study.

The paragraph number in the first column corresponds to the numbered paragraph of this section in which more detailed results are presented. Under "Item," a synopsis of the question is given, while the third column gives the "Category" of response that was studied for comparison.

COMPARISON OF SOME ATTITUDINAL RESULTS
WITH THOSE FROM A PREVIOUS STUDY

Para. No.	Item	Category	Prev. Study	Present Study	
				F	M
(1)	Rate neighborhood?	Excellent	28%	45.8%	33.3%
(2)	How many things liked?	Many things	54%	83.3%	62.5%
(3)	Things not liked?	*Open-ended	28%	33.3%	45.8%
(4)	How noisy or quiet?	Somewhat quiet	42%	37.5%	54.2%
(8)	Awareness of noise?	More aware	24%	37.5%	37.5%
(9)	Pollution question	Agree strongly	66%	58.3%	54.2%

* % is for those who stated some noise not liked.

Using the data reported in paragraphs (1) - (10), and the comparisons of paragraph (11), a general profile of the subjects can be formed.

Both males and, more markedly, females are more inclined to rate their neighborhood highly than those from the larger random sample. The present subjects also show a much stronger tendency than the general sample to report that they like "many things" about their neighborhood, with again the trend showing more in the females.

The subjects are more apt spontaneously to cite noise as a neighborhood problem than the random sample, with males mentioning noise more often. This would support the subjects' claim that they are more aware of noise than other people, which the respondents in the general sample claimed less often.

However, the subjects apparently are no more or less likely to perceive their neighborhoods as noisy than the general population, to judge from their use of the rating "somewhat quiet" of 46%, averaged over males and females, compared with the larger study which reported 42%.

The subjects represent a wide range of ages and incomes, tend to like their neighborhoods, and appear to be somewhat more highly sensitive to noise than a larger, random sample of people.

2.3 Listening Environment

The listening room is designed to resemble normal or usual living conditions, with two interconnected areas, one containing a couch, an easy chair, a coffee table, and a television, and the other being fitted with a sink, counter (with cupboards above), refrigerator, kitchen table and four chairs (a floor plan is shown in Figure 4). Both areas are fitted with a shag carpet, and a curtain was draped across the wall behind the television to reduce reverberation. The entire area measures 23'5" (7.14m) by 9'7" (2.92m), with a height of 8'5" (2.57m). The kitchen area is 8'2" (2.49m) long and is divided from the television viewing area by a partition 4'3" (1.30m) by 5" (0.13m).

Four subjects were seated in each area, resulting in eight listening positions. Four "Speakerlab 2" loudspeakers were used in the television area stacked in two "columns" of two, in the smaller more reverberant kitchen area, a large Advent loudspeaker was built into the ceiling over the table and a small Advent loudspeaker was set on top of the cupboards. Four amplifier channels were used, one for each of the kitchen area speakers and one for each of the television area columns, with separate volume controls for each channel.

The playback system consisted of a TEAC 3300 tape recorder, DBX 122 compander, a Hewlett Packard HP 350D attenuator and two Macintosh amplifiers, types 2100 and 250. This equipment was kept in an adjacent control room.

The sounds in the listening room could be monitored via a Bruel and Kjaer 1" microphone type 4117 concealed behind a painting and connected to a type 2205 sound level meter in the control room. During experimental sessions this was connected to a B and K 2307 level recorder and 4420 statistical distribution analyzer, so that the distribution of levels throughout the session for the total noise environment (due to speech, television, etc., as well as the recorded flyovers) could be compared with that due to the flyovers alone.

With nine people in the room, representing eight subjects and one experimenter, pink noise was played through all six speakers and the channels adjusted to give as near equal dBA levels as possible at each of the eight listening positions.

Then 1/3 octave pink noise responses were measured at each of the listening positions, with eight people in the room, and a large absorbent cushion (the "dummy") at the position being investigated. The responses were repeated with no people in the room, though the "dummy" was used. The microphone was positioned at the approximate position of the listener's head and the "dummy" was used to reduce reflections from the seat surface.

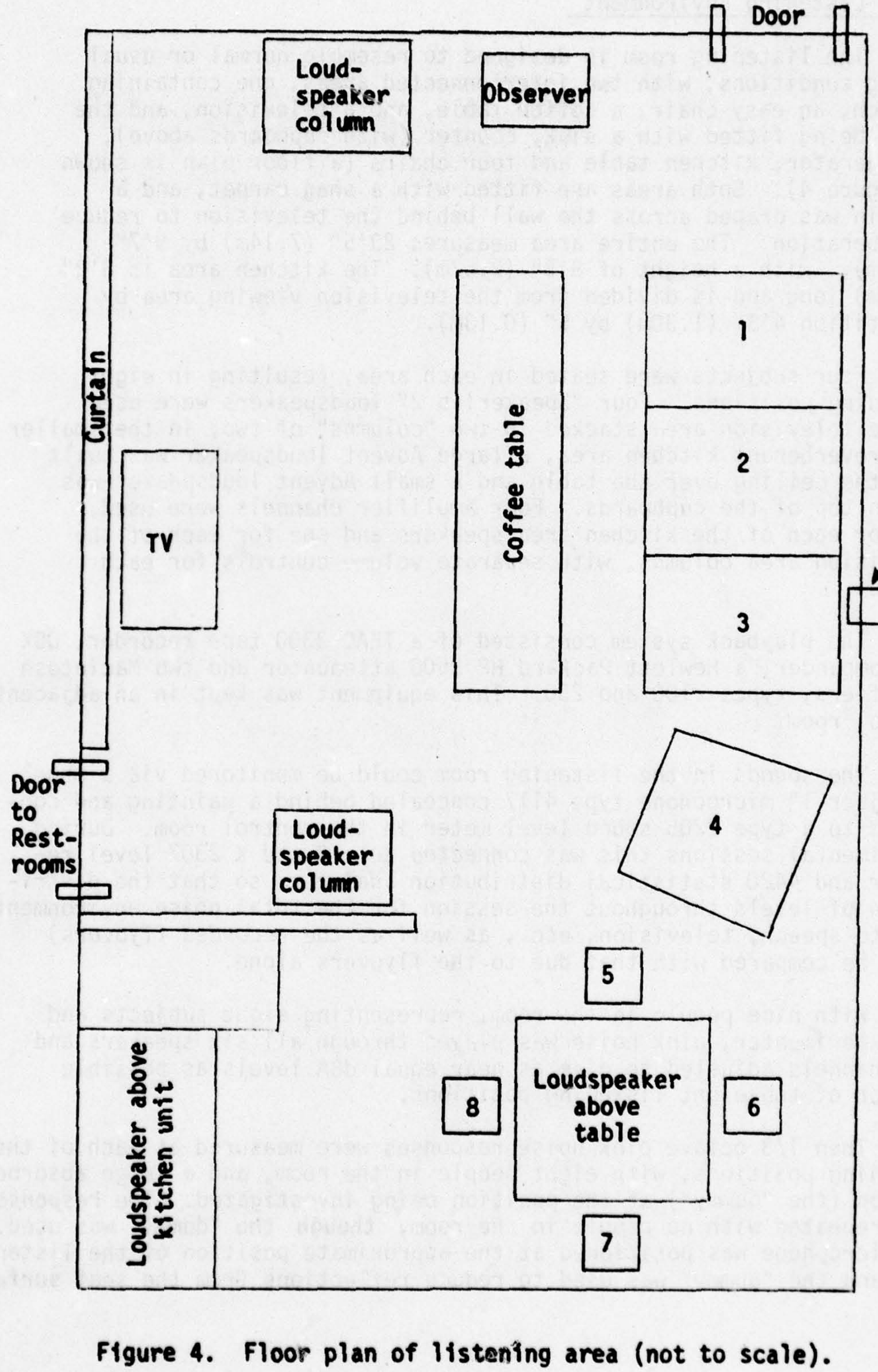


Figure 4. Floor plan of listening area (not to scale).

Differences were observable between the eight positions and, at any one position, between two conditions: with people and without people in the room. The eight positions clustered into two groups, the four in the kitchen area and the four in the television area.

Four flyovers were also played into the room and the peak dB(A) levels measured, with eight people and the "dummy" present, at each of the eight positions, and peak dB(A), peak PNLT and EPNL calculated at two positions, one in the kitchen area and one in the television area.

It was found that for pink noise, dB(A) varied between the eight positions by 1.2 dB (people present) and by 1.1 dB (people absent) (See Table III.). The two flyovers were found to vary in peak dB(A) between the eight positions (people present) by 1.9 dB for one and 1.5 dB for the other. Using the two positions (people present), the levels differed for the two flyovers by +1.3 dB and 0.0 dB for peak dBA, 0.0 dB and +1.0 dB for peak PNLT, and -2.6 and -0.4 dB for EPNL. (See Table IV.)

A further test was run using two flyovers to compare the presence and absence of people using one position in the television area. The differences between people present and people absent were found to be +1.2 and -0.1 dB (measuring peak dBA), +0.2 and -0.9 dB (peak PNLT), +0.5 and +0.4 dB (EPNL). (See Table V.)

It was, therefore, decided that the differences between people present and people absent were no greater than those between different positions and that the differences between the positions were not large enough to be significant. Further analyses were carried out without people present and using the "T.V. position" as being representative of all the listening positions.

Table III: dBA for pink noise measured at the eight listening positions.

	POSITION #								
	1	2	3	4	5	6	7	8	RANGE
People Absent *	75.3	74.8	75.0	75.2	75.3	75.7	75.9	75.0	1.1
People Present*	62.6	61.3	62.0	62.3	61.5	61.6	61.3	62.5	1.2

*There were different input levels for the two conditions.

Table IV: Levels measured for two flyovers at two listening positions, with people present.

		KITCHEN POSITION	TV POSITION	DIFFERENCE
Peak dBA	Flyover 1	67.4	66.1	1.3
	Flyover 2	65.1	65.1	0.0
Peak $PNdB_T$	Flyover 1	79.6	79.6	0.0
	Flyover 2	79.9	78.9	1.0
EPNdB	Flyover 1	80.2	82.8	-2.6
	Flyover 2	79.1	79.5	-0.4

Table V: Levels measured for two flyovers at a position in the television area, comparing people present with people absent.

		PEOPLE PRESENT	PEOPLE ABSENT	DIFFERENCE
Peak dBA	Flyover 1	75.7	76.9	1.2
	Flyover 2	70.4	70.3	-0.1
Peak $PNdB_T$	Flyover 1	90.3	90.5	0.2
	Flyover 2	85.3	84.4	-0.9
EPNdB	Flyover 1	89.8	90.3	0.5
	Flyover 2	82.9	83.3	0.4

2.4 Flyover Signals and Airport Noise Conditions

The flyovers selected for use in this study were recorded at SEATAC airport at two sites, almost directly under the flight path. One site was located at 3.04 n. miles frpm start-of-roll and the other at 5.21 n. miles from start-of-roll. Recordings from the 3.04 n. mile site were used in the standard condition and conditions #2, 3, 4 and 5, while 5.21 n. mile recordings were used in conditions #6 and #7. The original recordings were made using GenRad 1" and 1/2" electret microphones (types 1961 and 1962), Uher 4200 and 4400 stereo tape-recorders, and dbx 122 compander units to ensure that the largest possible signal-to-noise ratio was recorded.

The selected recordings were rerecorded, fading up the starts and down the ends to achieve the maximum duration free from interfering noises. The rerecordings were then recorded onto the experimental tapes, attenuating them to achieve the required levels, and ordering and timing their presentation to fit the required design.

The flyovers were originally recorded outdoors. It was found that the various stages of rerecording, together with the response of the playback system, produced a drop in high frequency response, measured in the presentation room, similar to that given in AIR 1081 (Ref. 7) as a typical house noise-reduction. Therefore, no further weighting was used to attain an indoor quality.

The seven conditions to be studied in this experiment were chosen to represent different realistic airport fleet mixes. The "standard" condition (condition #1) was chosen to represent the six basic categories of jet transport aircraft:

- 4-engined turbojet (707, DC-8)
- 4-engined turbofans (707, DC-8)
- 3-engined turbofans (727)
- 2-engined turbofans (737, DC-9)
- 4-engined high-bypass ratio turbofans (747)
- 3-engined high-bypass ratio turbofans (DC-10, L1011)

One take-off and one landing of each category was used, making twelve events. The average peak dBA sound level for each operation in each category was calculated for the recording (3.04 n. miles from start-of-roll) and these levels were used to determine the relative levels of the twelve events in condition #1. The order of presentation was randomized and spread unequally through the 90 minute experimental period, though four presentations occurred every 30 minutes. The presentation level of condition #1 was chosen to give an Leq value of 45 dBA. Conditions #2 and #3 were identical to #1, except that #2 was presented at a level 6 dB louder and #3,6 dB quieter.

The order and timing of the events in conditions #1, #2, and #3 are shown in Table VI.

Condition #4 was taken to represent airport conditions in the past which were controlled by relatively small fleets of predominately narrow body 4-engine jets. Six takeoff recordings were used, made at 3.04 n. miles from start-of-roll at SEA-TAC. (See Table VII).

Condition #5 was chosen to represent more modern conditions with large fleets, using high-bypass-ratio jets. Eighteen takeoff events recorded 3.04 n. miles from start-of-roll were used. (See Table VIII). Relative levels of the events within any condition were based on the actual average levels recorded at the 3 n. mile site. Note that L_{eq} presentation levels are almost identical for conditions #4 and #5 (52.1 and 51.9 respectively - see Table I).

Conditions #6 and #7 were based on recordings made at a site 5.21 n. miles from start-of-roll at SEA-TAC airport. At this site it was found that 727-200 takeoffs, using a "deep thrust" procedure, were an average 9 EPNdB lower than those using an in route climb takeoff procedure (as of 1976). The two conditions used the same recordings of the same twelve events, a mixture of takeoffs and landings of a variety of craft, at the relative levels measured at the site. In condition #6, the four recordings of 727-200 takeoffs were set at the levels for the usual or in route climb takeoff procedure, and in condition #7 these four recordings were set 8 dB lower. In presentation during the experiment, for both conditions the recordings were played at the same levels, except for the 727-200 takeoffs, resulting in a difference in L_{eq} of about 3 dBA. The events in conditions #6 and #7 are shown in Table VIII.

Table VI: Flyover events in Conditions #1, #2, and #3.

FLYOVER #		TYPE	OPERATION	PRESENTATION TIME *	PEAK dBA LEVEL**
Tape A	1	747	Takeoff	8	63.3
	2	DC-10	Takeoff	11	54.7
	3	DC-10	Landing	16	61.7
	4	DC-8(TF)	Landing	21	69.6
Tape B	5	727	Landing	37	65.4
	6	DC-8(TJ)	Takeoff	47	61.2
	7	737	Takeoff	50	58.6
	8	727-100	Takeoff	53	60.6
Tape C	9	727-200	Takeoff	69	63.8
	10	DC-8(TJ)	Landing	73	68.2
	11	DC-8(TF)	Takeoff	79	62.9
	12	DC-9	Landing	84	58.4

* Minutes from start of Tape A.

** Levels for Condition #1 (standard); add approximately 6 dB to obtain levels for condition #2; subtract approximately 6 dB for condition #3.

Table VII: Events in Condition #4.

FLYOVER #		TYPE	OPERATION	PRESENTATION TIME*	PEAK dBA LEVEL
Tape A	1	707(TF)	Takeoff	12	71.2
	2	DC-8(TJ)	"	22	68.5
Tape B	3	DC-8(TF)	Takeoff	34	68.9
	4	707(TF)	"	45	71.7
Tape C	5	DC-8(TF)	Takeoff	74	69.7
	6	DC-8-61(TF)	"	84	62.9

* Minutes from start of Tape A.

Table VIII: Events in Condition #5.

FLYOVER #		TYPE	OPERATION	PRESENTATION TIME*	PEAK dBA LEVEL
Tape A	1	DC-10-40	Takeoff	3	60.8
	2	DC-9	"	7	64.3
	3	727-200	"	11	70.4
	4	DC-10-40	"	17	61.1
	5	727-200	"	24	70.9
	6	727-100	"	26	67.4
Tape B	7	DC-10-10	Takeoff	32	59.4
	8	727-200	"	40	70.5
	9	DC-10-10	"	44	60.2
	10	DC-10-10	"	47	59.1
	11	737	"	49	65.7
	12	727-200	"	55	69.5
Tape C	13	DC-10-10	Takeoff	65	60.1
	14	DC-10-10	"	69	59.1
	15	727-200	"	73	69.3
	16	DC-10-40	"	75	60.8
	17	L1011	"	82	61.5
	18	727-200	"	87	70.0

* Minutes from start of Tape A.

Table IX: Events in Conditions #6 and #7.

FLYOVER #		TYPE	OPERATION	PRESENTATION TIME*	PEAK dBA #6	PEAK dBA #7
Tape A	1	747	Takeoff	4	60.5	59.0
	2	DC-8(TJ)	Takeoff	8	60.5	60.5
	3	DC-10	Landing	15	53.6	53.3
	4	DC-9	Landing	19	52.5	52.4
Tape B	5	727-200	Takeoff	37	60.5	51.3
	6	707(TF)	Takeoff	42	55.8	55.6
	7	DC-10	Takeoff	47	48.2	48.8
	8	727-200	Takeoff	53	59.7	52.6
Tape C	9	727-200	Landing	69	57.5	57.5
	10	DC-8(TF)	Landing	74	54.9	54.7
	11	727-200	Takeoff	82	60.1	52.2
	12	727-200	Takeoff	88	59.8	53.3

* Minutes from start of Tape A.

2.5 Physical Acoustical Analysis

As described above, a comparative analysis, involving the eight listening positions plus with and without persons present in the listening chamber, indicated that highly representative noise data would be obtained utilizing one listening position and with no persons present. Thusly, acoustic data for all conditions were obtained in real time at listening position 4 ("dummy" present) using a GenRad 1962-9601 1/2" electret microphone and 1560-P42 preamplifier, amplified with a GenRad 1933 sound level meter and analyzed using a GenRad 1921 real time analyzer connected to a PDP-11/10 computer. One-third-octave band analyses (from 50 Hz to 10,000 Hz center frequency) were performed every 1/2 second. From this data, a number of measures were computed for each flyover in any experimental condition, including peak dBA, peak $PNdB_T$(PNdB tone-corrected by the procedure in FAR-36) and peak dBH [using a weighting curve proposed by T. Higgins, which increases by 6dB/octave linearly up to 4KHz, passing through zero at 1KHz, and decreases by 6dB/octave from 4KHz (Ref.4)]. Duration-corrected versions of these units using various intensity ranges, including 10dB as used in FAR-36, and ASDS dwell times (the amount of time a specified level is equalled or exceeded) were also computed. Also, a mathematical weighting was applied to the measured data to reconstruct the sound levels that would have been necessary outside a house to produce the measured results inside. The weighting used was the inverse of that given in AIR 1081 (Ref. 7) as the grand mean for the attenuation produced by the different types of buildings and conditions considered.

Measures obtained for individual flyovers in any one condition were then combined in a number of different ways to give overall measures useful in comparing conditions. For instance, dwell times at a given level (using "inside" or "outside" data) were summed to give the total length of time that level was equalled or exceeded for a given condition. Log_{10} values of these total dwell times were also calculated for comparison with subjective responses. Log sums of duration-corrected dBA were calculated to determine Leq, and similar procedures were used for dBH and $PNdB_T$.

The arithmetic average of the peak dBA values for the flyovers in one condition was calculated, and the corrections added based on N, the number of flyovers occurring per hour in that condition, as in NNI. Using the corrections suggested by C. G. Rice (Ref. 8), the corrections investigated were 5 $Log_{10}N$, 10 LogN, 15 Log N and N/6. NNI uses 15 $Log_{10}N$ added to the average peak PNdB (minus a constant). As peak PNdB was not calculated in the analyses for this study, average peak values for dBA, $PNdB_T$ and dBA were used. A listing of the 109 methods examined are given in Appendix A and these various airport noise exposure measurement methods are discussed under Section 3.5 of this report.

3.0 RESULTS

The results are provided in seven subsections which correspond to the seven objectives of the program.

3.1 Objective 1. - Effect of Takeoff Procedure

Response to Questions 2, 3, and 4 (which are respectively concerned with "acceptability of the noise during usual leisure hours at home," "interference with listening activities," and "interference with speech activities") provide the basic results for evaluating the effectiveness of the deep thrust takeoff procedure. Figure 5 provides the response data. Acceptability is relatively high for both takeoff conditions; seventy-nine percent predict that the in route climb takeoff procedure condition would be acceptable during their usual leisure hours at home, while some eighty-four percent find the deep thrust takeoff procedure acceptable. This small difference cannot be considered as highly reliable due to the sample size utilized. However, the results do provide some indication that the deep thrust procedure condition is effective in terms of increasing community acceptability to flyover events as they occur in living quarters around airports. Turning to Question 3 which is concerned with listening interference, some seventy-five percent of the participants report no listening interference with the in route climb takeoff condition, while for the deep thrust takeoff condition, ninety-two percent report no interference with listening. This increase is reliable with greater than 90 percent confidence using a one-tailed test in conjunction with a normal distribution function; participants do show less interference with listening activities as a function of the deep thrust takeoff procedure condition. The third set of data in Figure 5 (flyover occurs but no interference with listening) shows that for almost all persons reporting no interference with listening activities, that a flyover did occur during a listening activity. The final set of data for Question 3 provides extent that participants were annoyed who did report interference with a listening activity. At most, those who reported interference were moderately annoyed by the interference with the listening activity and slightly more so for the in route climb takeoff condition than for the deep thrust condition. Question 4 deals with interference as a participant is speaking. The in route climb takeoff procedure condition shows slightly less interference (96% no interference) than the deep thrust takeoff condition (92% no interference). This difference is too small to be considered reliable and is primarily due to the fact that for many of the participants, no flyovers occurred as they were speaking and to a slightly greater extent for the in route climb takeoff procedures over the deep thrust takeoff condition. As for listening interference (Question 3), those few participants experiencing interference with speaking rated this interference as being, at most, moderately annoying.

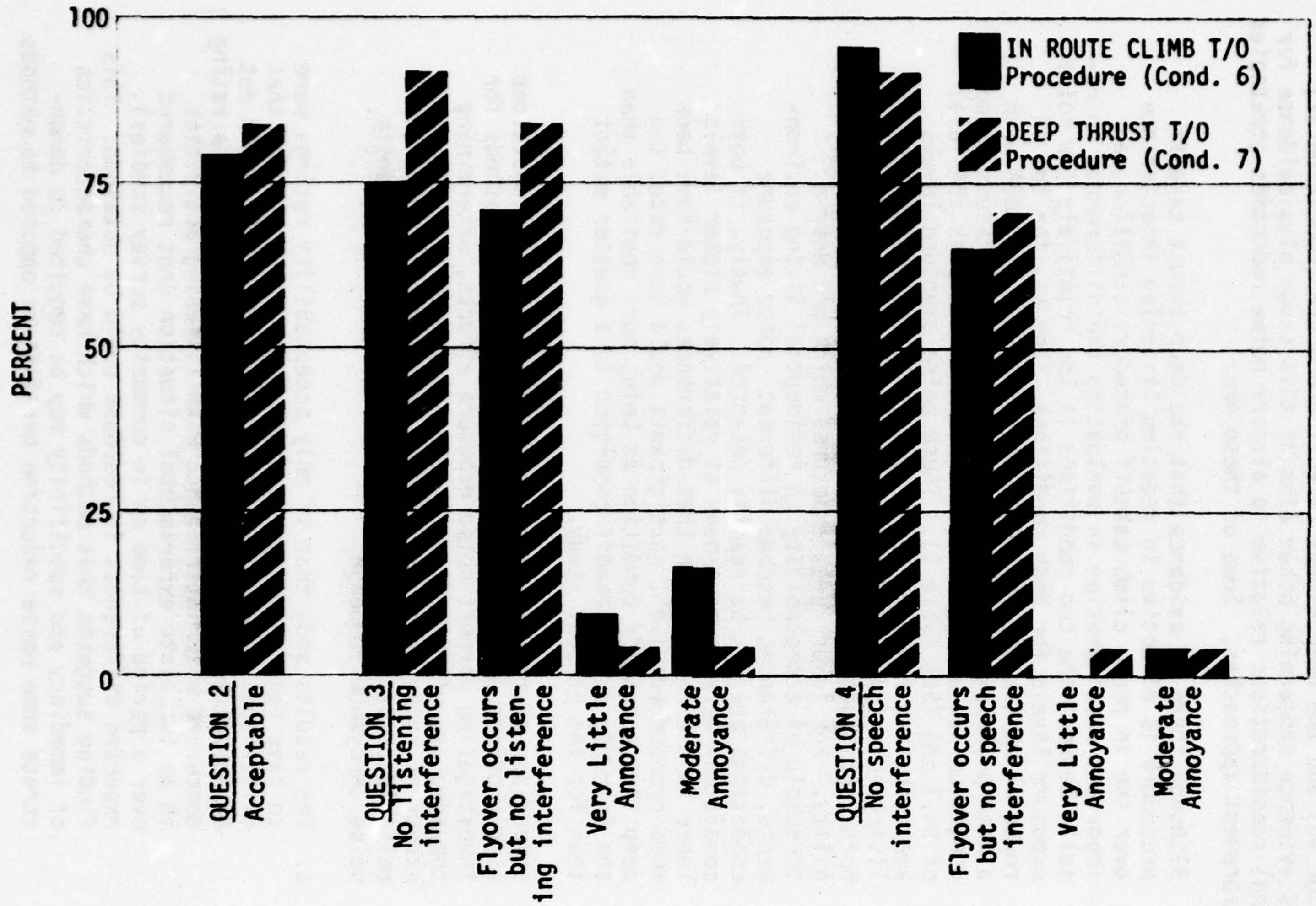


Figure 5. Response results for comparison of in route climb takeoff procedure condition vs. deep thrust takeoff procedure condition.

This comparison of results for the in route climb takeoff procedure (condition #6) and the deep thrust takeoff procedure (condition #7) provides evidence concerning other aims of this study plus evidence for additional considerations relative to airport noise reduction strategies and measurement approaches. Some of these are:

1. Although there is evidence that the deep thrust takeoff procedure is effective in reducing listening interference over the in route climb takeoff procedure condition, an important consideration in evaluating the differences in results between the two conditions is the relatively low noise exposure levels for both conditions. The L_{eq} for the in route climb takeoff procedure condition was 41.6 dBA with a mean peak level of 57.0 dBA, while the deep thrust takeoff condition had an L_{eq} of 38.9 dBA and a mean peak dBA level of 54.3 dBA (See Table I). These noise exposure levels are both in a range of being acceptable for residential living activities (see reference 9); noise exposure for both conditions is at or below a threshold of acceptability. For lower level exposures which are near a threshold of acceptability in residential living environments, differences between different noise exposure conditions are not as readily detected. Thusly, if both conditions were to have been at relatively higher levels, there is the expectation that differences would have been more pronounced; i.e., participants would have rated the deep thrust takeoff condition as being more desirable than the in route climb takeoff condition to a greater extent than for the present study.

2. Comparison of results based on these two takeoff conditions also provides guidance relative to selection of methods for investigating airport noise exposure effects, determining the adequacy of methods such as L_{eq} and mean peak dBA, and extent of noise level differences required to produce a reliable or detectable increase or decrease in community noise annoyance response.

   a. The results show that if only acceptability ratings were to have been obtained, it could have been concluded that differences between the two noise environments would not be perceived by the community. However, by using a rating concerned with interference with listening activities in an immediate experimental situation (not remembered over a period of time as in community survey studies), expected differences in response could be obtained. This finding suggests that methods which have characteristics of immediacy and specificity may be required to demonstrate some noise reduction benefits as opposed to methods

which are aimed at measuring a more general attitude of airport noise acceptability or noise annoyance.

b. In respect to two of the noise exposure methods employed, L_{eq} and mean peak dBA level, the absolute acceptability difference (Question 2), which is a kind of general evaluation of the two noise conditions, would lead to the conclusion that L_{eq}'s of mean peak dBA are not satisfactory methods for measuring airport noise exposure, at least not satisfactory for the range of levels investigated. However, the listening interference results indicate that there are response differences to these two noise environments and that the differences are reflected in the L_{eq} and mean peak dBA airport noise measurement methods. The L_{eq} for the deep thrust takeoff condition is 2.7 dBA less than for the in route climb takeoff condition, as is the mean peak dBA difference.

c. Evidence relative to the problem of a reliable or detectable increase in noise exposure is also provided. Since the difference between the two takeoff conditions is 2.7 dBA for either L_{eq} or mean peak dBA level and since the lower condition showed less listening interference at greater than a 90 percent confidence point, there is evidence that a decrease of 2.5 to 3.0 dBA (L_{eq} or mean peak dBA) is a reliable and detectable difference relative to listening interference. This should be utilized as a tentative conclusion at present and examined further as remaining objectives are considered along with evidence from other applicable studies.

3. Another consideration involves airport noise reduction strategies. Due to the wide use of the 727 aircraft and its noise level characteristics, this aircraft is one of the controlling factors relative to reducing noise exposure levels around airports. As indicated previously (see Ref. 1), measurements show that utilization of a particular takeoff procedure will reduce takeoff noise levels some 9 EPNdB at 5.21 n. miles from brake release. There is evidence that this noise reduction benefit occurs continuously from approximately 4 to 10 n. miles from brake release, but the extent of the benefit is not well documented across this distance. Use of this procedure will appreciably reduce noise exposure in these areas if the procedure is utilized by the total fleet of 727 aircraft out of an airport. However, there is an increase in noise over usual takeoff procedures beginning at approximately 10 n. miles from brake release. It is

estimated that this increase over an in route takeoff procedure is in the neighborhood of 2 EPNdB. When considering this deep thrust procedure as a noise reduction strategy, the extent of area benefitted by the procedure plus the extent of increase in noise levels at distances greater than 10 n. miles from brake release should be determined via a measurement program. Our expectation is that an average increase of 2 EPNdB for one type of aircraft at this distance from an airport (lower noise levels) will not create an additional noise exposure problem.

4. A final consideration involves the acceptability of indoor airport noise exposure or determining a threshold of acceptability. For both conditions some eighty percent of the respondents reported that these two noise environments would be acceptable, "during your usual leisure hours at home." Since there is a strong possibility that participants under-predict acceptability of a noise environment in a laboratory setting as opposed to a completely natural or actual home living situation, it would be concluded that both of these noise exposure conditions are at or below a threshold of acceptability. Further evidence for such a conclusion is that interference with a listening acitivity was, at most, rated "moderately annoying" and for but twelve percent of the participants. Depending on the noise attenuation afforded by typical homes around airports, which can vary from 20 to 30 dBA, outdoor L_{eq} would range from 62 to 72 dBA for the in route climb takeoff condition (#6) which is tentatively considered as the threshold for acceptability. Thusly, outdoor NEF values with no nighttime correction would range from approximately 27 to 37 NEF and with a nighttime correction range in the neighborhood of 30 to 40 NEF. There is strong evidence that the 10 dB nighttime correction is not required at the levels of condition #6 with peak levels at 60.5 dBA (Ref. 9), plus other evidence (Refs. 3 and 9) that the nighttime correction of 10 dB is too great. Therefore, in terms of current usage of NEF as an airport noise exposure measurement method, indoor airport noise environments are acceptable in the 30 to 40 NEF range, the precise level being a function of noise attenuation provided by the dwelling.

3.2 Objective 2. - "Old" Aircraft Mix vs. "New" Aircraft Mix

As for the preceding objective, participants' responses to Questions 2., 3., and 4. provide the results for comparing an older airport noise environment (smaller numbers of 4-engine narrow body jet aircraft) to a newer noise environment (larger numbers of aircraft with emphasis on high bypass powered jet aircraft); see Tables VII and VIII for aircraft and noise levels employed for these two conditions. Figure 6. provides the response data for comparing the two airport noise environments. Overall acceptability can be considered as relatively low since but 25 percent of the participants predicted that the old aircraft mix would be acceptable "during your usual leisure hours at home," while some 42 percent predicted that the new aircraft mix condition would be acceptable. Due to the number of participants in the experiment, this difference in acceptability in favor of the new aircraft mix is not reliable at a 90 percent confidence point, but the outcome does support a conclusion that the new airport mix tends to be as acceptable or somewhat more acceptable than the old aircraft mix. For response to Question 3. which involves listening interference due to the flyover intrusions, some 12 percent report no interference with listening activities when experiencing the old aircraft mix, while more than 54 percent of the participants report no interference with the new aircraft mix. This some 42 percent difference between response to the two noise exposures is a reliable difference at a greater than 99 percent confidence level using the normal distribution function and a two-tailed test. Participants clearly experienced the new aircraft mix of 18 aircraft intrusions vs. six intrusions for the old aircraft mix as providing less interference with listening activities. This difference was not due to no-occurrence-of-flyovers during listening activity. Annoyance was much more pronounced to the old aircraft mix as some 42 percent of the participants reported that they were "very much annoyed" by the interference with listening, due to the older mix, while but 8 percent reported that they were "very much annoyed" by interference due to the new aircraft mix condition. Turning to interference with participants' own speech (Question 4. of Figure 6.), 50 percent reported no interference with their own speech to the old aircraft mix, while approximately 71 percent reported no speech interference to the new aircraft mix. That 50 percent reported no interference to the older mix is primarily due to no flyover intrusions occurring during a speech activity in that only 8 percent of the participants reported that a flyover occurred while they were speaking but that there was no interference. However, for the newer mix, 42 percent reported no interference with speech but that a flyover did occur during a speech activity. The new aircraft mix is from all points of view more desirable than the old aircraft mix.

Comparison of the participants' response results to the old

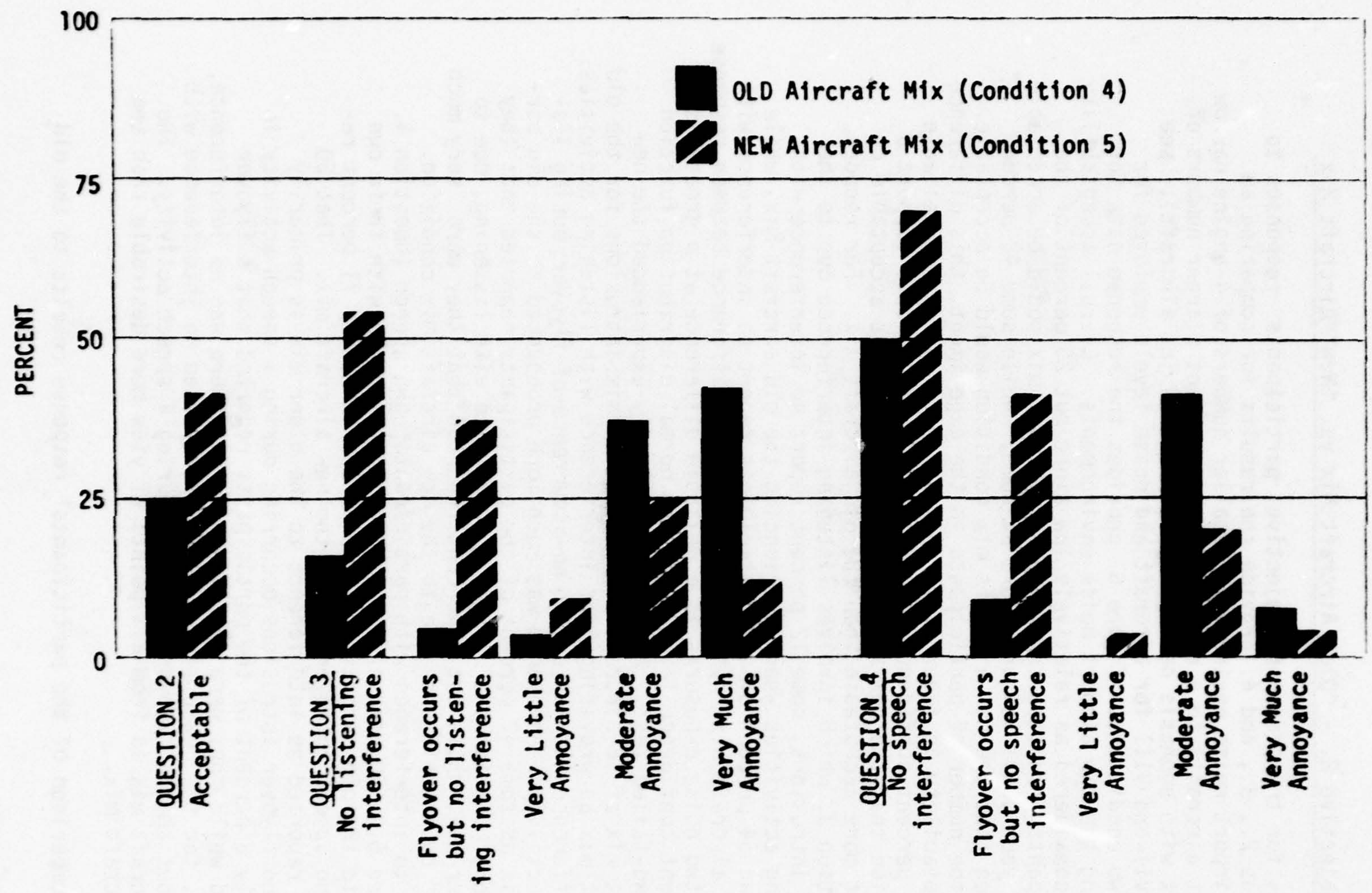


Figure 6. Response results for comparison of old aircraft mix vs. new aircraft mix.

aircraft mix vs the new aircraft mix provides information relative to some of the other objectives of this study. As shown in Table I, number of flyovers for the older mix was 6, with an L_{eq} of 52.1 dBA and a mean peak dBA level of 68.8. There were 18 flyovers for the newer mix with an L_{eq} of 51.9 dBA and a mean peak dBA level of 64.4. From the standpoint of obtaining noise measurements, the 0.2 dBA L_{eq} difference between the two conditions is equivalent to zero difference, so the L_{eq}'s for both conditions are equal. However, participants' response results show that the new aircraft mix is more acceptable and is less interfering with listening and speech activities than the old aircraft mix. This leads to the conclusion that L_{eq} does not adequately measure the response differences for these two noise environments. On the other hand, the mean peak dBA level is 4.4 dBA less for the new aircraft mix as opposed to the old aircraft mix (68.8 dBA less 64.4 dBA equals 4.4 dBA). This decrease of 4.4 dBA is in agreement with participants' ratings so it could be concluded that the mean peak dBA method for measuring airport noise exposure is more valid than L_{eq}.

3.3 Objective 3. - Scaling of Noise Exposure Evaluation Methods

The interest relative to this objective is doubling or halving of annoyance response as a function of various airport noise exposure methods. This problem is analogous to the expectation that for single flyover events, annoyance or loudness response is doubled or halved with a 9 to 10 dB increase or decrease in level. The magnitude estimation psychophysical method is intrinsically suited to this problem so magnitude estimation results in connection with Conditions 1, 2, and 3 are emphasized for this analysis. It will be recalled that Conditions 1, 2, and 3 include the Standard Condition plus the exact same set of 12 flyovers raised 6 dB for Condition 2 and lowered 6 dB for Condition 3. All 48 subjects responded to these three conditions.

Results are presented in Figure 7 separately for Groups I - III and Groups IV - VI along with those for Conditions 6 and 7 to which only Groups I - III responded and Conditions 4 and 5 to which only Groups IV - VI responded. In Figure 7, the mean for the Log Magnitude Estimation ratings are plotted as a function of L_{eq}. Although experimental conditions were identical for Groups I - III and Groups IV - VI, there is dissimilarity of response to Conditions 1, 2, and 3 for these two groups of different persons. Also, if response as a function of L_{eq} is considered for the additional conditions to which Groups I - III responded (Cond. 6, in route climb takeoff and Cond. 7, deep thrust takeoff), the relationship between the Magnitude Estimation ratings and L_{eq} has much greater linearity for Groups I - III than that for Groups IV - VI. For Groups IV - VI, ratings to Conditions 4 and 5 ("Old" and "New" airport noise environments) are, to a considerable extent, not in agreement with those for Conditions 1, 2, and 3 using L_{eq} as the noise exposure method. L_{eq} scales response quite well for Groups I - III but not at all well for Groups IV - VI.

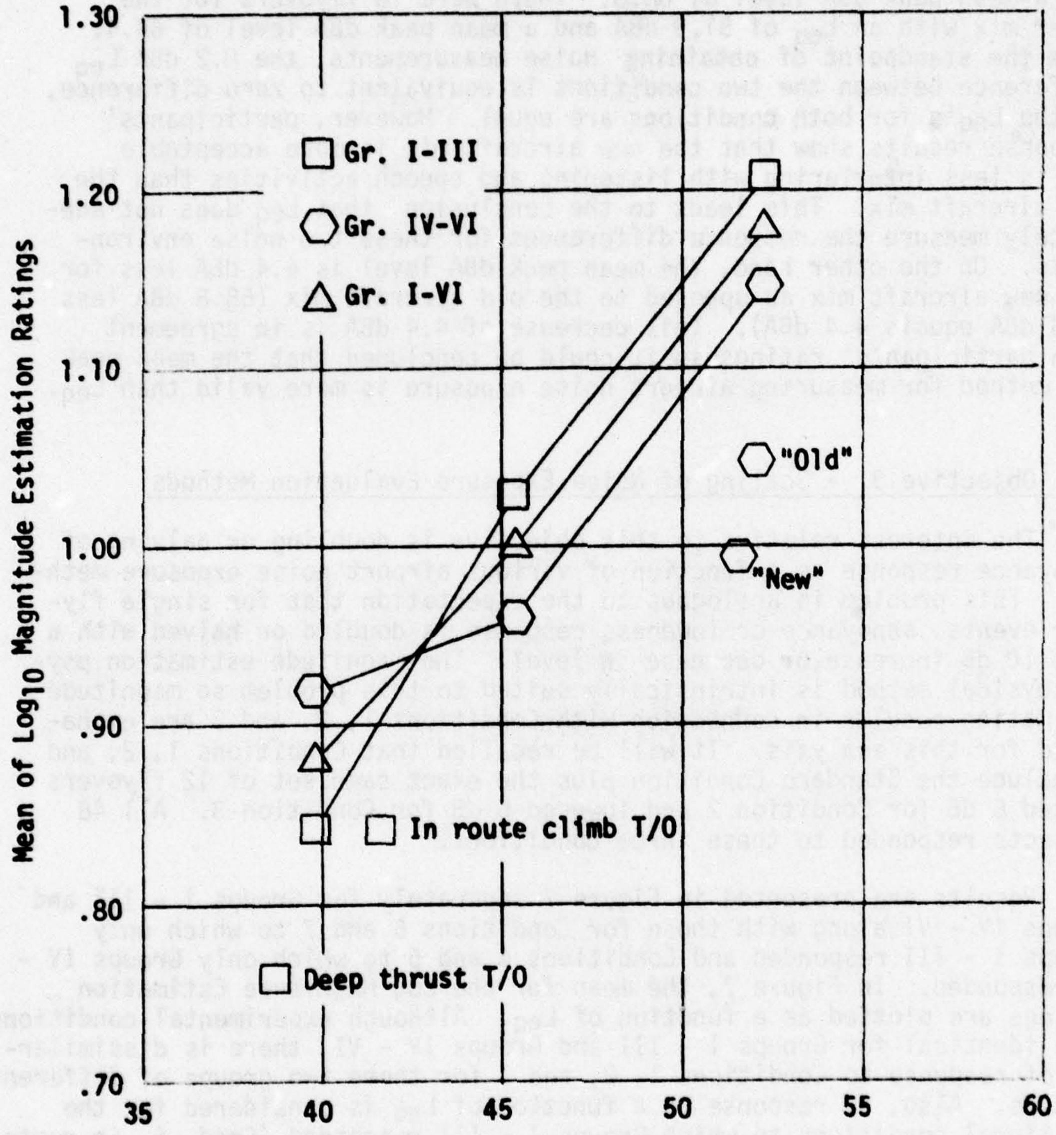


Figure 7. Mean Log Magnitude Estimation ratings as a function of L_{eq}.

Figure 8. presents the results of Figure 7. using Mean Peak dBA as the noise exposure method. As for the results of Figure 7, linearity between the response and noise measures is much more pronounced for Groups I - III than for Groups IV - VI. However, linearity is improved for the relationships based on Groups IV - VI response in that the point for the "New" airportnoise condition is very close to the plotted line for Conditions 1, 2, and 3. Also, linearity is slightly improved for results based on Groups I - III response.

Figure 9. utilizes NEF methodology as the noise exposure method. As for the comparisons based on Leq and Mean Peak dBA, the relationship between Magnitude Estimation ratings and the NEF method has much greater linearity for Groups I - III results than for Groups IV - VI results.

The product moment coefficient of correlation is a method for quantifying linearity so it is applied to the results of Figures 7., 8. and 9. as a means of confirming the previous data interpretations. The larger the coefficient, the greater the linearity. Results are given in Table X and very much confirm the interpretations based on inspection of

Table X. Product Moment Coefficients of Correlation for Mean Magnitude Estimation Results vs Airport Noise Exposure Methods

Groups	Noise Exposure Methods: Leq	Mean Peak dBA	Day NEF
I - III	0.990	0.999	0.999
IV - VI	0.734	0.860	0.787
I - III plus IV - VI	0.851	0.921	0.888

Figures 7., 8. and 9. Linearity is almost perfect based on Groups I - III response regardless of the noise exposure method utilized. For Groups IV - VI response, Mean Peak dBA shows the highest extent of linearity, NEF is next highest, and Leq demonstrates the least amount of linearity. For results based on the mean Magnitude Estimation ratings for all ten points (Groups I - III plus Groups IV - VI), again Mean Peak dBA shows the greatest linearity, NEF is next, and Leq is last (see Table X.)

In respect to the present objective of scaling commonly used airport noise exposure methods, the above evaluation led to the conclusion to utilize Groups I - III results based on all five conditions and the mean results for all groups based on Conditions 1, 2, and 3. These three conditions were introduced into the experiment as a basis for investigating the scaling problem. Utilizing the standard condition (Condition 1) as a reference, the increase or decrease in each noise exposure method required to double or halve annoyance response is obtained. These four comparisons

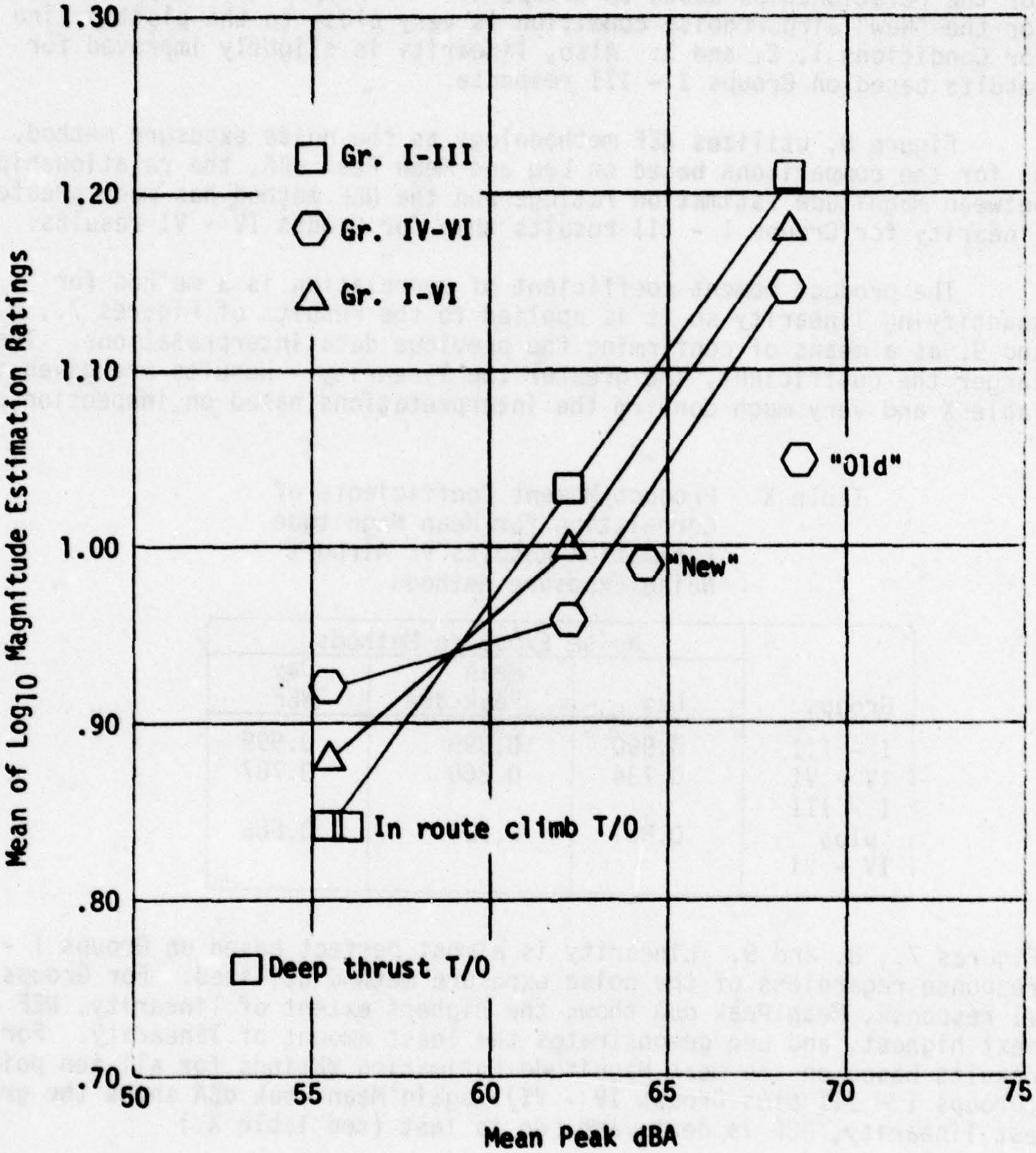


Figure 8. Mean Log Magnitude Estimation ratings as a function of mean peak dBA levels.

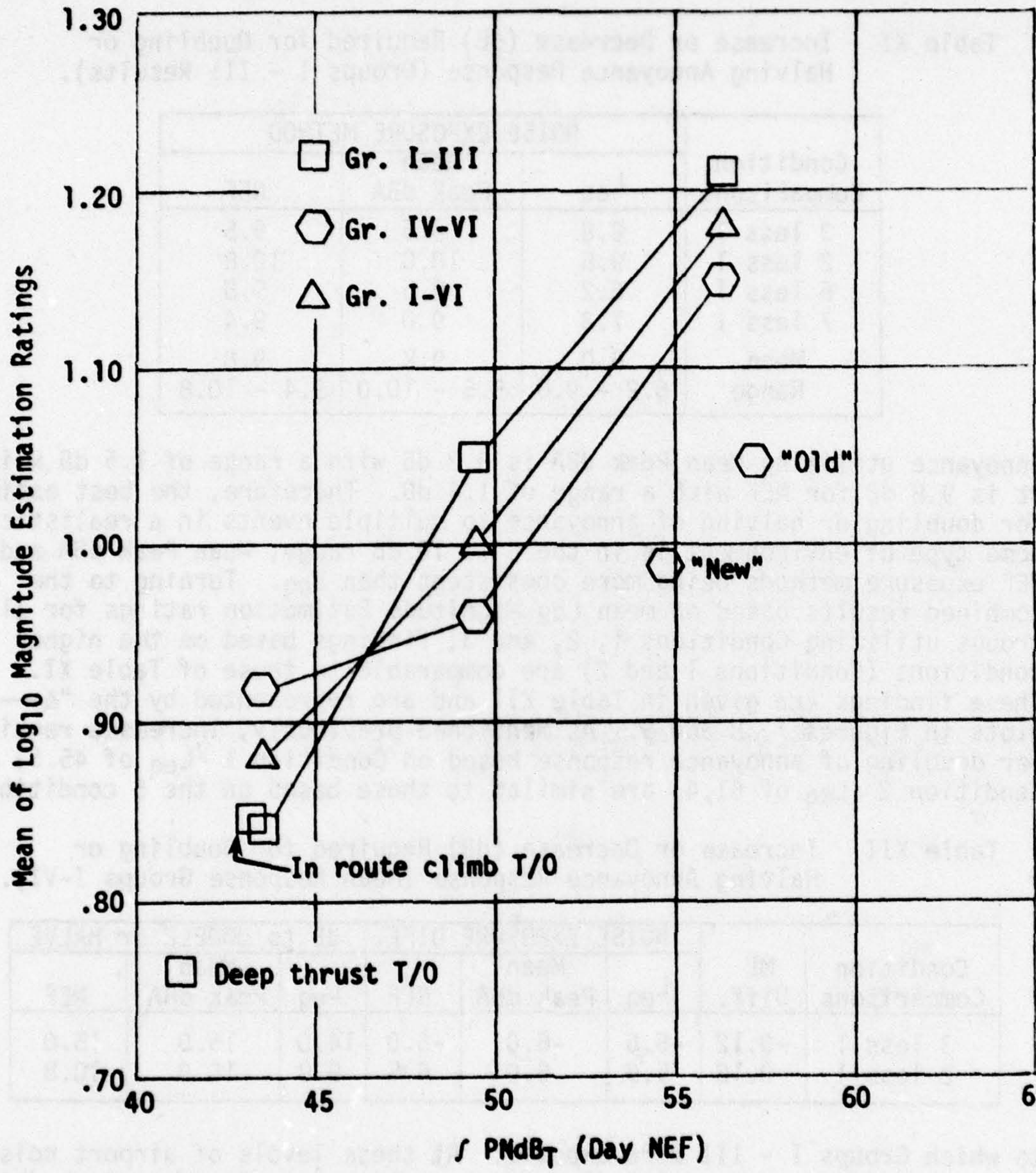


Figure 9. Mean Log Magnitude Estimation ratings as a function of integrated PNdB$_T$ (Day NEF).

are given in Table XI for the Groups I - III results. The mean level for doubling or halving annoyance based on the L_{eq} airport noise exposure method is 8 dB with a range of 3.6 dB. Mean level for doubling or halving

Table XI. Increase or Decrease (dB) Required for Doubling or Halving Annoyance Response (Groups I - III Results).

Condition Comparisons	NOISE EXPOSURE METHOD		
	L_{eq}	Mean Peak dBA	NEF
3 less 1	8.8	9.5	9.5
2 less 1	9.8	10.0	10.8
6 less 1	6.2	8.5	9.5
7 less 1	7.3	9.0	9.4
Mean	8.0	9.2	9.8
Range	6.2 - 9.8	8.5 - 10.0	9.4 - 10.8

annoyance utilizing Mean Peak dBA is 9.2 dB with a range of 1.5 dB while it is 9.8 dB for NEF with a range of 1.4 dB. Therefore, the best estimate for doubling or halving of annoyance to multiple events in a realistic home type of environment is in the 8 to 10 dB range, Mean Peak dBA and NEF exposure methods being more consistent than L_{eq}. Turning to the combined results based on mean Log Magnitude Estimation ratings for all 6 groups utilizing Conditions 1, 2, and 3, findings based on the higher level conditions (Conditions 1 and 2) are comparable to those of Table XI. These findings are given in Table XII and are represented by the "Δ——Δ" plots in Figures 7, 8 and 9. As mentioned previously, increases required for doubling of annoyance response based on Condition 1 (L_{eq} of 45.5) and Condition 2 (L_{eq} of 51.4) are similar to those based on the 5 conditions

Table XII. Increase or Decrease (dB) Required for Doubling or Halving Annoyance Response (Mean Response Groups I-VI).

Condition Comparisons	ME Diff.	NOISE EXPOSURE DIFF.			dB to DOUBLE or HALVE		
		L_{eq}	Mean Peak dBA	NEF	L_{eq}	Mean Peak dBA	NEF
3 less 1	-0.12	-5.6	-6.0	-6.0	14.0	15.0	15.0
2 less 1	0.18	5.9	6.0	6.5	9.8	10.0	10.8

to which Groups I - III were exposed. At these levels of airport noise exposure, an increase of 9.8 dB using L_{eq}, 10.0 dB using Mean Peak dBA, and 10.8 dB using NEF are required for doubling of annoyance response. However, the comparison between Condition 1 (L_{eq} of 45.5) and Condition 3 (L_{eq} of 39.9) provides a different result. The increase or decrease to double or halve annoyance response is 14 or 15 dB depending on the noise exposure method employed. For these commonly used methods, scaling of annoyance response is level-dependent and these airport noise exposure methods are not linear.

Before emphasizing some application implications for these findings and as a means of placing the levels investigated in perspective, estimated outdoor noise exposure levels are provided in Table XIII. Both Conditions 1 and 2 are estimated to be at an outdoor level that could be considered not ideally suited for residential dwellings around airports (see Ref. 9) while the noise exposure of Condition 3 would be considered as being compatible with residential living (Ref. 9).

Table XIII. Estimated Outdoor Levels for Three Noise Exposure Methods Utilizing 25 dB as Average for Building Attenuation.

Condition	Leq Presentation Level	EST. OUTDOOR LEVELS		
		L_{eq}	Mean Peak dBA	NEF
3	39.9	64.9	81.4	29.9
1 (Std)	45.5	70.5	87.4	35.5
2	51.4	76.4	93.4	41.4

Application implications are:

1. Doubling or halving of annoyance response is level-dependent. For noise exposure levels which may not be ideally suited for residential living, annoyance response using methods such as Leq, Mean Peak dBA, and NEF doubles as a function of an 8 to 10 dB increase in level. However, at levels which may be at or well below a threshold of acceptability, much greater reductions (some 50% greater) are required to obtain a comparable decrease in annoyance response. This finding suggests that there is a resistance point at which further reductions in airport noise will result in but minimum reduction in community annoyance response.

2. Doubling or halving of annoyance response findings based on these laboratory results can be generalized to actual airport environments. As indicated in the just previous application implication, doubling or halving of annoyance response is level-dependent and that in a range of exposure levels where airport noise could be considered a problem, approximately 10 dB increase in NEF results in a doubling of annoyance response. Are there data from airport community studies which tend to confirm this finding? Reference 10 provides results relevant to this question. For this study, unbiased annoyance response was obtained to two questions from a random sample of persons

living around Seattle Tacoma International Airport. These two questions were:

No. 2. What things do you dislike about living around here?

No. 3. What do you consider the most serious problem in the community right now?

A respondent who mentioned airport noise to either of these questions is rated as being genuinely annoyed and concerned with airport noise. The percent response for an estimated median NEF of 40 and 30 are as follows:

	Median NEF 40	Median NEF 30	NEF 40/30 Ratio
Ques 2. "Among things disliked"	48.0%	26.3%	1.82
Ques 3. "Most serious problem"	43.1%	22.6%	1.91

For both annoyance measures, almost two times as many persons are rated as being annoyed by the higher exposure level than at the lower level. These results do tend to confirm the findings of the present study that a 10 dB reduction in NEF will reduce annoyance response by some 50 percent. However, this finding should not be applied in an absolute sense as the median levels of 40 and 30 NEF were obtained from NEF contour determinations. Median levels for the respondents may be 43 and 33 NEF respectively as an individual NEF for each respondent was not obtained.

3.4 Objective 4. - Determining the Increase or Decrease in Noise Exposure which is Perceived as a Reliable Increase or Decrease in Noise Annoyance

This particular objective is concerned with determining minimum changes in airport noise exposure that would result in an increase or decrease in community noise annoyance. As an example, utilizing the NEF method, is a reduction from 35 to 32 perceived as an improvement? In order to obtain relatively precise data that will bear on this objective, a number of conditions with differences in the neighborhood of 2 to 3 dB have been ideal. Also, category scaling is considered the more appropriate psychophysical method for investigating this objective (Ref 11, p.2-8). Minimum differences between Conditions 1, 2 and 3 are on the order of 6 dB (depending on the noise exposure method used) with smaller differences for Conditions 4 vs 5 ("Old" vs "New") and Conditions 6 vs 7 (in route climb vs deep thrust). Therefore, we will begin with the category results to conditions 1, 2 and 3 and augment the analyses by examining the results for Conditions 4 vs 5 and Conditions 6 vs 7.

Results for Questions 2, 3, and 4 are given in Figure 10. Question 2 is concerned with "acceptability" of the noise exposure condition, Question 3 with "no listening interference", and Question 4 with "no speech interference". For the low level noise exposure condition (L_{eq} of 39.9), some 67 percent of the participants reported that the condition was "acceptable", 51 percent found the medium level (L_{eq} of 45.5) "acceptable", while some 36 percent rated the high noise condition as "acceptable". Comparable results were found for Question 3 concerning "no listening interference". For this particular objective, we are interested in whether or not response differences are reliable between adjacent conditions. Table XIV provides the results for response differences to adjacent noise exposure levels for "acceptability" and "no listening interference".

Table XIV. Reliability of Adjacent Differences for Acceptability and No Listening Interference Response Results.

	ACCEPTABILITY			NO LISTEN. INTERFER.		
	% Diff.	SED*	Rel. Point	% Diff.	SED*	Rel. Point
Low less Medium	16.3	9.88	95%	14.1	10.03	92%
Medium less High	15.5	9.99	94%	17.8	9.83	96%

* Standard Error of the Difference

An evaluation of the differences shows that there is a 92 percent or greater expectation that the differences are reliable. This leads to the conclusion that for L_{eq}, Mean Peak dBA, and NEF airport noise exposure methods, 6 dB differences result in a perceptible increase or decrease in noise annoyance. This 6 dB difference can be considered as an upper minimum reliable difference. Comparisons between "old" vs "new" airport noise environments and the in route climb takeoff vs deep thrust takeoff noise conditions provide evidence relative to the question: What is the minimum increase or decrease in noise exposure which results in a perceptible difference that is reliable?

As shown under <u>3.2 Objective 2.</u>, the "new" airport noise exposure was rated as a significant improvement over the "old" airport noise exposure condition. However, the L_{eq}'s for these two conditions were 51.9 and 52.1 with Mean Peak dBA levels of 64.4 and 68.8 respectively for "new" vs "old". This result suggests two conclusions:

1. That L_{eq} does not adequately measure differences between these noise exposure conditions.

2. That Mean Peak dBA does reflect the response differences found and that a difference of approximately 4 dBA is an estimate of a reliable difference based on the Mean Peak dBA exposure method.

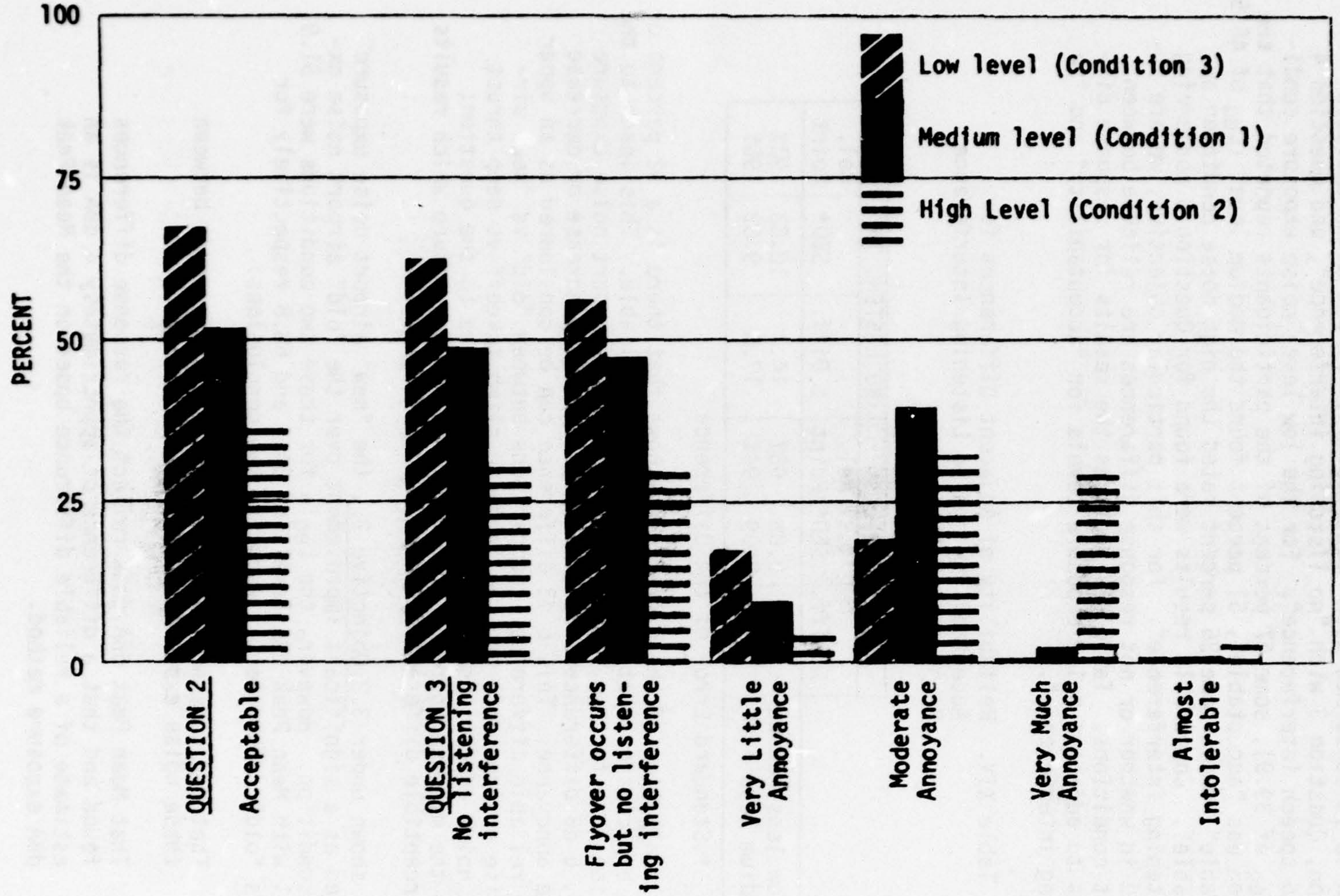


Figure 10. Response results for comparing Low, Medium, and High level (Conditions 3, 1, and 2) noise exposure conditions.

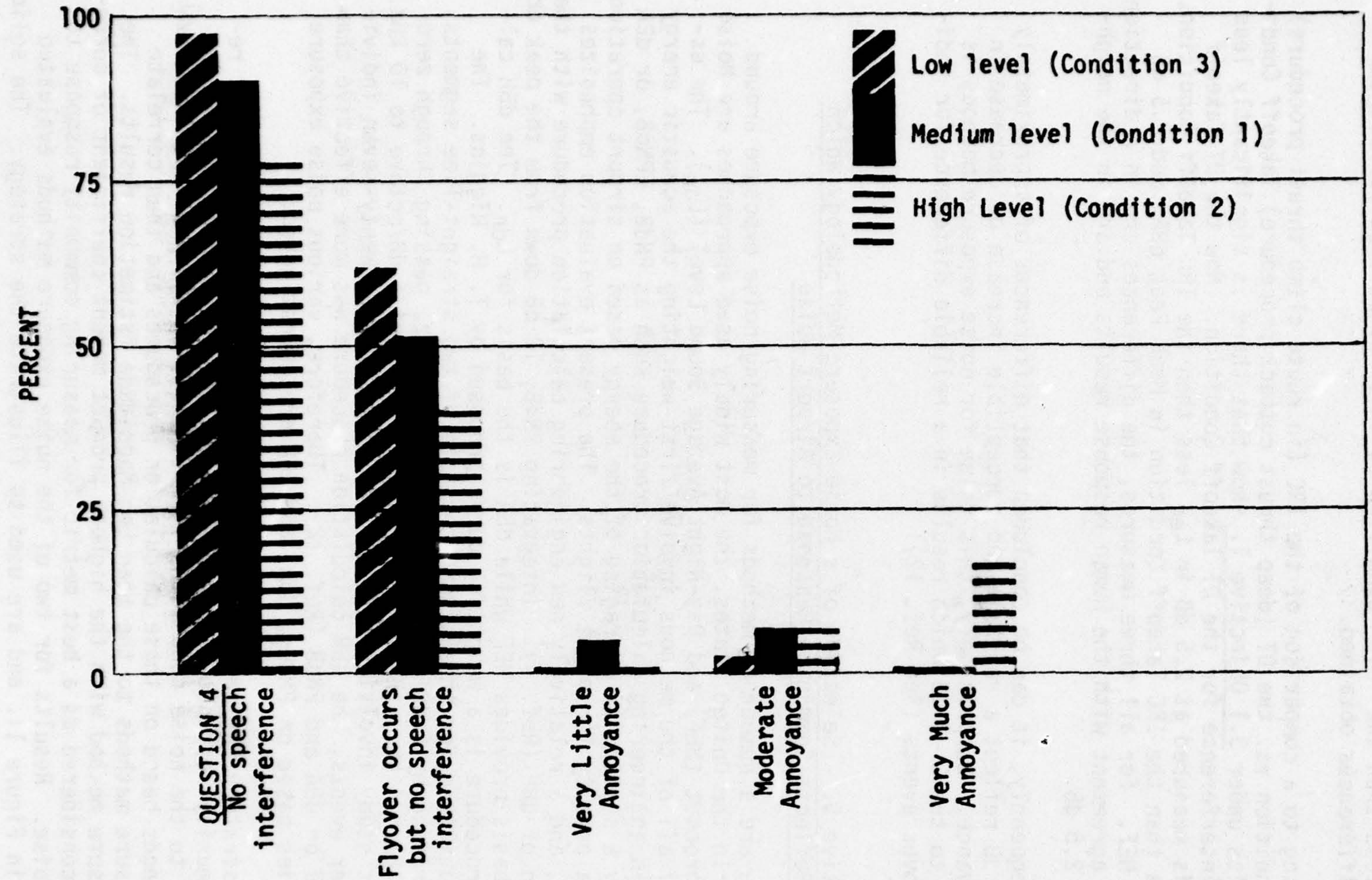


Figure 10 (continued). Response results for comparing Low, Medium, and High level (Conditions 3, 1, and 2) noise exposure conditions.

Using NEF as the noise exposure method, the "new" airport noise condition is 2.5 dB less than the "old" condition so this method does reflect the response differences obtained.

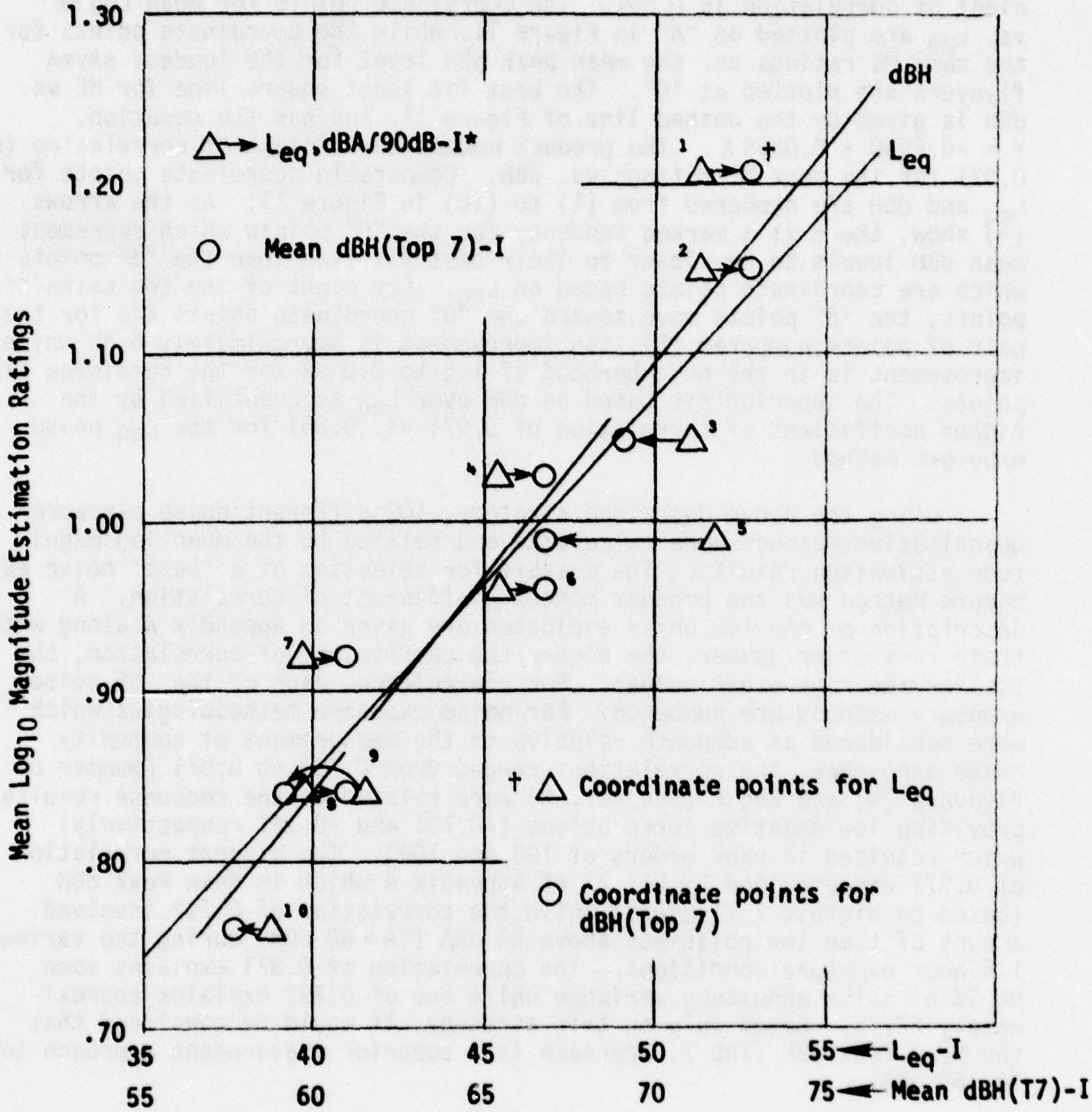
Turning to a comparison of the IRC (in route climb thrust procedure) Takeoff Condition vs. the DT (deep thrust cutback procedure) Takeoff Condition, results under 3.1 Objective 1. show that there is significantly less listening interference for the DT Takeoff Condition. Now the DT Takeoff Condition is measured at 2.5 dB in L_{eq} less than the IRC Takeoff Condition, 2.7 dB less than the IRC Takeoff Condition in Mean Peak dBA, and 2.5 dB less using NEF. For all three measures, the differences are in a direction that is in agreement with the human response results and are in the neighborhood of 2.5 dB.

Consequently, it can be concluded that differences of approximately 2.5 to 4.0 dB reflect a reliable and perceptible increase or decrease in noise annoyance. Surprisingly, this value for noise exposure methods is very close to the 2 - 3 dB which results in a reliable difference for individual flyover events (See Ref. 12).

3.5 Objective 5. - Selection of a Noise Exposure Methodology which Best Reflects Community Response to Airport Noise

There are a number of methods for measuring noise exposure around airports. In the United States, the most widely used approaches are Noise Exposure Forecast (NEF) and Day-Night Average Sound Level (L_{dn}). The essentials of all of the methods involve first weighting the acoustic energy utilizing an engineering calculation procedure such as PNdB, EPNdB, or dBA followed by a summing or averaging of the energy based on airport operations including a penalty for night flights. The present evaluation emphasizes $PNdB_T$, dBA, and a relatively new engineering calculation procedure with the designation of dBH (Ref. 4). Integrating $PNdB_T$ 10 dB down from the peak on an energy basis provides NEF while dBA is the basis for L_{dn}. The dBH calculation procedure is a weighting curve proposed by T. H. Higgins. The curve, as utilized for this study, consists of two straight-line segments, the first rising by 6 dB/octave from 50 Hz to 4 kHz, passing through zero at 1 kHz. From 4 kHz, the curve falls at a slope of 6 dB/octave to 10 kHz. In a recent study involving response of 60 persons to twenty-seven individual flyover events, the dBH calculation procedure was more effective than those based on dBA and PNdB (Ref. 12). Therefore, various noise exposure methodologies based on $PNdB_T$, dBA, and dBH are investigated.

The strategy for selection of a noise exposure method that best reflects community response is to apply the three engineering calculation procedures to the noise conditions investigated, develop various noise exposure methods based on these calculation procedures and then correlate these exposure methods to the mean Log Magnitude Estimation results. The noise exposure method with the highest product moment coefficient of correlation is considered as a best metric for measuring community response to aircraft noise. Results for two of the noise exposure methods evaluated are given in Figure 11. and are used to illustrate the strategy. The solid



*I means an indoor noise spectra is analyzed.

Figure 11. Least square best fit lines for mean $\log_{10}$ magnitude estimation ratings vs. two noise exposure methods.

line of Figure 11. is the least square best fit line for the ten mean $\log_{10}$ Magnitude Estimation (ME) ratings vs. L_{eq}. The equation of this best fit line is $Y = -0.0318 + 0.0220X$ and the product moment coefficient of correlation is 0.851. The coordinate points for mean Log ME vs. L_{eq} are plotted as "Δ" in Figure 11. while the coordinate points for the same ME ratings vs. the mean peak dBH level for the loudest seven flyovers are plotted as "O". The best fit least square line for ME vs. dBH is given by the dashed line of Figure 11. and has the equation, $Y = -0.6950 + 0.0255X$. The product moment coefficient of correlation is 0.971 for the mean ME ratings vs. dBH. Comparable coordinate points for L_{eq} and dBH are numbered from (1) to (10) in Figure 11. As the arrows (→) show, there is a marked tendency for the "O" points which represent mean dBH levels to be closer to their best fit line than the "Δ" points which are coordinate points based on L_{eq}. For eight of the ten pairs of points, the "Δ" points move toward the "O" coordinate points and for the pair of points numbered (5), the improvement is approximately 5 dB while improvement is in the neighborhood of 1.5 to 2.0 dB for the remaining six points. The superior fit based on dBH over L_{eq} is quantified by the higher coefficient of correlation of 0.971 vs. 0.851 for the L_{eq} noise exposure method.

Using the above described strategy, 109 different noise exposure quantitative methods were calculated and related to the mean log magnitude estimation results. The measure for selection of a "best" noise exposure method was the product moment coefficient of correlation. A description of the 109 units evaluated are given in Appendix A along with their rank order number; the higher the coefficient of correlation, the smaller the rank order number. For convenience, each of the 109 noise exposure methods are numbered. For noise exposure methodologies which were considered as adequate relative to the measurement of community noise annoyance, the correlations ranged from 0.792 to 0.971 [Number of flyovers (N) and Log N (see Ref. 8) were related to the response results providing low negative correlations (-0.107 and -0.141 respectively) which resulted in rank orders of 108 and 109]. The highest correlation of 0.971 was provided by No. 77 of Appendix A which is Mean Peak dBH (based on highest 7 flyovers) while the correlation of 0.792 involved amount of time the noise was above 60 dBA (TA > 60 dBA) during the various 1.5 hour exposure conditions. The correlation of 0.971 explains some 94.3% of noise annoyance variance while one of 0.792 explains approximately 62.7%. Based only on this strategy, it would be concluded that the Mean Peak dBH (Top 7) approach is a superior measurement approach to TA > 60 dBA.

Before we examine the results in detail, findings for some of the commonly used noise exposure methods are given in Table XV. For the three basic engineering calculation procedures investigated (dBA, $PNdB_T$, and dBH), the rankings are consistant. Regardless of the method of measuring noise exposure (energy summation or mean peak level), prediction capability is least for dBA, next greatest for $PNdB_T$, and greatest for dBH. Also, utilizing mean peak levels for the seven loudest flyovers is more effective for all calculation procedures over their respective energy summation approaches. Finally, dBH is superior to dBA and $PNdB_T$

Table XV. Product Moment Coefficients of Correlation of Mean Ratings Results vs. Noise Exposure Methods.

APPENDIX A. NO.	NOISE EXPOSURE METHOD		COEFFICIENTS OF CORRELATION	RANK ORDER
1	L_{eq} - dBA	*I	0.851	94
5	NEF (no night flights)	I	0.889	77
3	L_{eq} - dBH	I	0.945	30
71	Mean Peak dBA (Top 7)	I	0.913	63
74	Mean Peak $PNdB_T$ (Top 7)	I	0.936	33
77	Mean Peak dBH (Top 7)	I	0.971	1

*Noise analyses based on flyover signals as heard by the subjects (Indoor analyses).

regardless of the method used to measure noise exposure (rank orders of 1 and 30). With minor exceptions, predictive capability of the three calculation procedures using other noise exposure methods follows the order of Table XV. These exceptions will be noted as other comparisons from Table A-1 of Appendix A are emphasized.

As discussed in Appendix A, 1/3-octave analyses of the various airport noise conditions were completed in real time just as the subjects heard the noises (Indoors - "I") and also an inverse of the average house weighting network was used to provide outdoor ("O") noise exposure results. Noise exposure methods No.'s 1 to 6 can be used to illustrate the effect of using the outdoor noise data as shown in Table XVI.

Table XVI. Comparison of Results Based on Indoor vs. Outdoor Spectra for Energy Summation Methods.

APPENDIX A. NO.	NOISE EXPOSURE METHOD		RANK ORDER
1	L_{eq} - dBA	I	94
2	L_{eq} - dBA	O	72
5	NEF	I	77
6	NEF	O	31
3	L_{eq} - dBH	I	30
4	L_{eq} - dBH	O	5

For all three engineering calculation procedures, utilizing the outdoor spectral analyses improves the relationship between noise exposure methods and the subject's ratings of the noise conditions. These results are supporting to the commonly used practice of measuring community response to airport noise on the basis of outdoor noise analyses.

As indicated above, the lowest correlation obtained between noise condition ratings and a noise exposure method involved the amount of time in minutes that the noise was equal-to-or-greater than 60 dBA (TA > 60 dBA I). This result does not mean that time above a particular level is necessarily a poorer predictor of community noise annoyance than those methods which directly involve a decibel measure of the noise exposure. What it does mean is that we do not have a mathematical transformation on time above a particular level which provides a linear correspondence to the subject's ratings (In this sense it is a poorer predictor). Table XVII provides some results bearing on this problem. A logarithmic transformation was applied to each of the noise exposure methods listed in Table XVII

Table XVII. Results Based on Time (min.) Noise is Equal-to-or-greater than a Specified Level (dBA & dBH).

APPENDIX A. NO.	NOISE EXPOSURE METHOD		RANK ORDER OF METHOD	RANK ORDER OF Log (Method)
7 & 8	TA > 60 dBA	I	107	82
9 & 10	TA > 80 dBA	O	106	87
11 & 12	TH > 60 dBH	I	93	56
13 & 14	TH > 85 dBH	O	70	99
15 & 16	TH > 80 dBH	O	97	83

and in four of the five comparisons, the log transformation improved the predictive capability. Also, this is one of the few comparisons (No.'s 13 vs. 14) for which the dBH calculation procedure was not clearly superior to dBA and $PNdB_T$. Time above a particular level is a useful noise exposure method for specific criterion applications and in particular for those situations involving "complete descriptions of the noise" (see Ref. 2).

Another comparison involves the effectiveness of the FAR-36 duration correction. A number of studies which were concerned with response to individual flyover events have provided results which support the effectiveness of the FAR-36 duration correction (as examples see Refs. 7 & 12). Are comparable results achieved for response to groups of flyovers presented over a realistic time period? Table XVIII presents results utilizing mean peak levels vs. mean of the duration corrected levels. For all three engineering calculation procedures, prediction capability is reduced by including the duration correction.

Table XVIII. Comparisons of Results Based on Mean Peak Levels vs. Mean FAR-36 Duration Correction Levels.

APPENDIX A. NO.	NOISE EXPOSURE METHOD	RANK ORDER
17	Mean Peak dBA (All) I	58
26	Mean dBA_D (All) I	103
19	Mean Peak $PNdB_T$ (All) I	55
27	Mean EPNdB (All) I	92
21	Mean Peak dBH (All) I	17
28	Mean dBH_D (All) I	69

An hypothesis that merits consideration is: community response to aircraft noise is a function of a loudest set of flyover intrusions. This hypothesis is intuitively appealing since it supports the possibility that there is a threshold of annoyance or disturbance and that lower level signals do not contribute to aircraft noise annoyance response. Some results relative to this hypothesis are given in Table XIX. For the dBA comparisons, rank orders are not appreciably changed by basing the Mean Peak on the loudest 6 or 7 flyovers from the various noise conditions. However, for both $PNdB_T$ and dBH, predictive capability is appreciably increased by utilization of mean peak levels for the loudest 6 or 7 flyovers.

Table XIX. Comparison of Mean Peak Levels Based on All Flyovers vs. Loudest 6 Flyovers vs. Loudest 7 Flyovers.

APPENDIX A No's.	NOISE EXPOSURE METHOD	RANK ORDERS		
		All	Top 6	Top 7
17,18,71	Mean Peak dBA I	58	60	63
19,20,74	Mean Peak $PNdB_T$ I	55	28	33
21,22,77	Mean Peak dBH I	17	3	1

Before examining some results concerning the inclusion of a direct correction for the number of flyovers experienced (see Ref. 8), an empirical ground rule for determining differences between rank orders is considered. A repeat physical acoustical analysis was completed for No. 1 of Appendix A which is "L_{eq} - dBA I" and related to the subjective response results; the results of the repeat analysis are given as No. 32 of Appendix A. The rank order for the original physical acoustical analysis of L_{eq} - dBA is 94 while it increases to 101 for the repeat analysis. Based on this result, it will be concluded that a difference of 10 rank

orders is required to achieve an actual difference between rank orders for the various exposure units.

Some findings from a recent report (Ref. 8) have indicated that a direct correction for number of flyover intrusions to noise exposure methods may improve predictive capability of the exposure methods. Table XX provides some comparisons relative to these findings. Four direct corrections for number of events are added to the mean peak levels for the three calculation procedures evaluated. Using a difference of ten rank orders as a rule for concluding that there is an actual improvement in predictive capability, the addition of 10 log N to mean peak dBA levels does not result in an increase. However, for mean peak $PNdB_T$ and dBH it is considered that there is an actual improvement in predictive capability. Utilizing N/6 as a direct correction to the mean peak dB levels provides no improvement for any of the three calculation procedures nor does 15 log N. On the other hand, the addition of 5 log N improves the predictive capability for mean levels based on all three engineering calculation procedures and that 10 log N improves the relationship for Mean Peak $PNdB_T$ and Mean Peak dBH, are in agreement with the results of Reference 8. Results of Reference 8 show that addition of 5 log N provided the greatest amount of improvement but that the optimum constant "K" was approximately 7 or 8.

Table XX. Changes in Rank Orders Due to a Direct Correction for Number (N) of Flyover Events.

APPENDIX A No's.	NOISE EXPOSURE METH.	All	ADDITIONS TO MEAN PEAK			
			10 log N	N/6	15 log N	5 log N
17,33,34, 39,42	Mean Peak dBA (All)	58	51	56	64	48
19,35,36, 40,43	Mean Peak $PNdB_T$(All)	55	36	52	50	38
21,37,38, 41,44	Mean Peak dBH (All)	17	6	12	18	7

3.6 Objective 6. - Determine and Evaluate the Validity of the Equal Energy Hypothesis

A method which quantifies and accurately reflects community response to environmental noise is a useful tool. It permits evaluations of and comparisons between diverse noise environments regardless of the noise sources. However, all of the single number approaches such as L_{eq}, L_{dn}, NEF, NNI, CNEL do not account for some of the more qualitative aspects of a particular noise environment and for some situations, may suppress or cover up significant aspects of a noise exposure situation. The results of Figure 1. are an example where mean peak dBA approach noise exceeds aircraft takeoff noise but is not reflected by L_{eq} based on the average

manner that the airport operates. Thus, it is not surprising that airport noise exposure methods based on the assumption that equal weighted acoustic energy results in equal (on the average) community response, do not universally and accurately reflect community response. Results which specifically contribute to an evaluation of this widely used assumption are summarized.

As presented in 3.1 Objective 1. - Effect of Takeoff Procedure, significantly less interference with listening activities was reported for the "deep thrust" (DT) takeoff procedure in contrast to the in route climb (IRC) procedure. For both L_{eq} and mean peak dBA, the DT takeoff procedure noise exposure was 2.7 dB less than that for the IRC takeoff procedure. Thus, it would be concluded that an exposure method based on energy summation is effective. However, the mean peak dBA method is equally effective in corresponding to the human response data.

Turning to the comparison between Conditions 4. and 5. ("Old" Noise Environment vs. "New" Noise Environment), the L_{eq} difference for the two conditions is but 0.2 dB which indicates that exposure as measured by L_{eq} is identical. However, the human response results show that, from all points of view, the "New" Noise Environment is more desirable or acceptable than the "Old" Noise Environment. Clearly, L_{eq} does not reflect this perceived difference. The mean peak dBA level for the "Old" was 68.8 while it was 64.4 dBA for the "New" Noise Environment, a reduction of 4.4 dBA. Thus, the mean peak dBA exposure method does reflect the perceived acceptability of the "New" over the "Old" Noise Environment.

Some indirect evidence relative to the adequacy of energy summation exposure methods is provided in, 3.3 Objective 3. - Scaling of Noise Exposure Evaluation Methods. For every comparison (see Table X.), mean peak dBA showed a higher linear relationship to the human response results than did L_{eq} or NEF and NEF is slightly superior to L_{eq}.

A final set of results which bears on the adequacy of the equal energy hypothesis involves those which were concerned with selection of a noise exposure methodology which best reflects community response to airport noise. However, the findings cannot be divorced from the engineering calculation procedures used to weight the energy prior to summing. As shown in Table XV, for the three engineering calculation procedures investigated (dBA, $PNdB_T$, and dBH), mean peak levels for the loudest seven flyovers resulted in higher correlations with the response data than did energy summations based on their respective calculation procedures. Thus, it would be concluded that exposure methods based on mean peak levels are more effective than those based on energy summations. However, the energy summation based on dBH is slightly superior to exposure methods based on mean peak dBA or $PNdB_T$ and is clearly superior to L_{eq} - dBA, L_{eq} - dBH accounting for some 89% of the common variance between an exposure method and human response results while L_{eq} - dBA accounts for 72% of the common variance.

In summary, on the whole results show that mean peak level exposure methods are superior to energy summation methods but that the effectiveness of a method is also very much a function of the engineering calculation

procedure used to weight the acoustic energy.

3.7 Objective 7. - Threshold of Acceptability During Evening Leisure Hours

One of the factors which makes it difficult to establish a threshold of acceptability for airport noise environments in living areas is the response variability to airport noise. Some persons find relatively high noise exposure levels acceptable while other persons are annoyed by quite low level intrusions. In addition, there is variability of response for the same person from one situation to another but to the exact same noise exposure experience. Another factor which is relevant to this study is that the participants have been asked to make a prediction concerning their response in the future and as though they were living around an airport. It may be that advantages such as living close to work or recreational activities, the neighborhood, schools, etc., would offset airport noise annoyance and increase the noise level for establishing a threshold of acceptability (accept higher noise levels). Persons may predict a lower noise exposure acceptability than that based on experience in the actual airport area. With these conditions in mind, the results to question number 2., "If the sounds experienced here were to occur in the same manner during your usual leisure hours at home, would they be acceptable to you? Yes____ No____", are examined. Due to the variability between and within persons concerning response to airport noise environments and also that a prediction of future response is being solicited, we will use 50% as a threshold benchmark..

A description of the seven noise conditions along with the percent of participants who report that they would find a particular condition acceptable "during their usual leisure hours at home" is provided in Table XXI. Percent acceptable ranges from 25% for the "Old" Noise Environment (No. 4) to 83% for the DT (deep thrust) T/O procedure condition (No. 7). It is quite interesting that the condition with the fewest number of flyovers is the least acceptable. In Figure 12., percent acceptable is plotted as a function of mean peak dBA levels. Using the accepted benchmark from psychophysics of 50%, conditions No. 7, 3, 6, and 1 (all four administrations) are at or above a threshold or acceptability while conditions 5, 2, and 4 would be considered unacceptable. However, condition No. 5, which simulated a "new" airport environment using the largest number of flyovers for any condition, is approaching the threshold of being acceptable. Although it was not possible to systematically investigate the effect of number of operations relative to establishing a threshold of acceptability, there is some evidence that the number of operations is not of high importance. For the three conditions which had identical L_{eq}'s of 51.4, 52.1, and 51.9 (conditions 2, 4, and 5), predictions of being acceptable were highest for condition 5 with 18 flights and lowest for condition 4 with 6 flights. Thus, for the present, number of intrusions is not considered in establishing a threshold of acceptability. Since the mean peak dBA level is 62.4 for condition No. 1 and all four administrations of this "standard" condition resulted in acceptability percents of 51 to 69 percent, the mean peak level of 62 dBA is recommended as a lower limit for a threshold of noise exposure acceptability

Table XXI. Description of seven 1.5-hour noise conditions and percent predictions of acceptability during usual leisure hours at home.

#	CONDITION DESCRIPTION	NO. OF FLYOVERS	CONDTION L_{eq}	MEAN PEAK dBA	RANGE OF PEAK dBA	PERCENT ACCEPTABLE
1	Standard - A	12	45.5	62.4	54.7-69.6	62
1	" - B	12	"	"	" - "	69
1	" - C	12	"	"	" - "	69
1	" - D	12	"	"	" - "	51
2	Stand. plus 6 dBA	12	51.4	68.4	60.7-75.6	36
3	Stand. minus 6 dBA	12	39.9	56.4	48.7-63.6	67
4	"Old" Noise Envir.	6	52.1	68.8	62.9-71.7	25
5	"New" Noise Envir.	18	51.9	64.4	59.1-70.9	42
6	IRC T/O	12	41.6	57.0	48.2-60.5	79
7	DT T/O	12	38.9	54.3	48.8-60.5	83

and with an upper mean peak dBA level Of 64. This 62 to 64 mean peak dBA range is higher than the suggested threshold of Reference 11, which stated "For indoor speech activities and for comfortable listening levels to television and radio, it is concluded that flyovers with peak levels not greater than 65 dBA are acceptable." A more detailed review of results to all four administrations of condition No. 1 follows and tends to confirm that this higher level criterion of mean peak dBA levels of 62 to 64 is in agreement with the ratings.

As described in 2.1 Procedures and Response Measures, each of the 48 subjects was exposed to three consecutive standard conditions (three evenings in succession), informed that it was the standard condition, and that it was assigned the number "10". The aim was for the participants to learn and remember this 1.5-hour exposure situation so that they could rate subsequent conditions relative to this standard condition. Results for the category items 2, 3, and 4 to these four standard conditions are given in Figure 13. For Question 2, whether-or-not noise condition would be acceptable during usual leisure hours at home, for the three evenings when subjects were informed that it was a standard condition, acceptability ranged from 62-69%. However, for the fourth presentation of this standard condition when subjects were instructed to rate the same condition relative to the standard and not informed that it was the exact same condition, acceptability dropped to 51%. These results lead to the following conclusions:

- Persons cannot recognize or remember a noise exposure experience.

- Informing persons that an exposure situation is a "standard" induces a response set that increases acceptability.

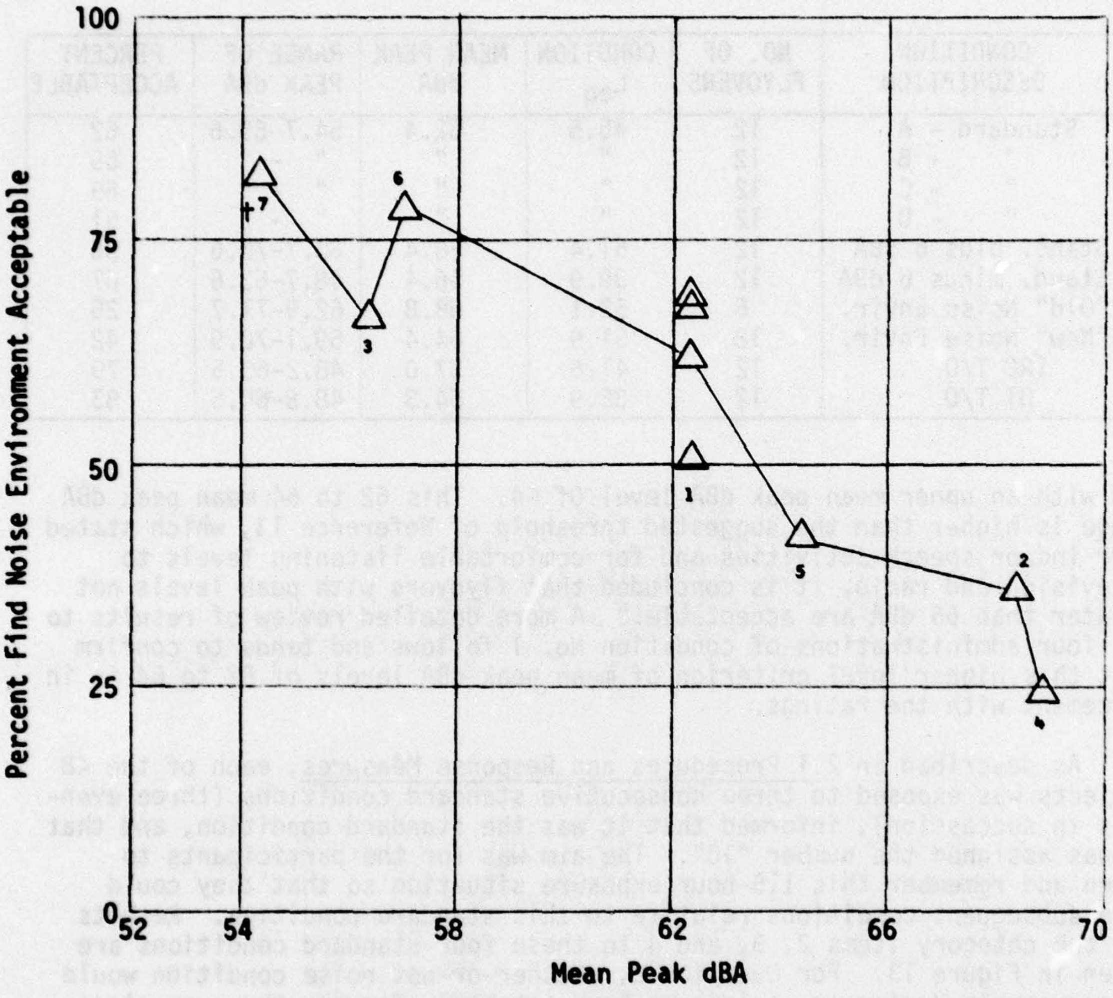


Figure 12. Percent acceptable as a function of mean peak dBA for the seven noise conditions.

To Question 3., there is also an increase in listening interference for the standard session where participants were not informed that it was a fourth presentation of the same noise exposure situation. Again, a response set concerning informing subjects that the first three sessions were standard conditions is hypothesized. Ratings concerning speech interference (Question 4) were consistent across all four sessions with more than 85% of the participants reporting no speech interference for all four sessions and approximately 55% reported that they were speaking as a flyover occurred. Speaking interference as perceived by the speaker is not as pronounced as listening interference. A final comment concerning annoyance ratings as a result of listening interference bears on establishing a threshold of acceptability. Results in Figure 13 show that, at most, participants rated interference with listening activities as "Moderately Annoying." It is this result, plus case history experience with persons living in airport noise exposure areas, which led to increasing the mean peak dBA from 62 to a range of 62 to 64 dBA as a threshold of acceptability.

Some more qualitative observations concerning response to aircraft noise exposure in a simulated natural setting are helpful in understanding aircraft/airport noise annoyance in general. There was behavioral evidence that the activity in which a person is engaged at the time that an intrusion occurs affects his annoyance response. For example, early in a session, persons engrossed in playing cards or in a face-to-face conversation would question as to whether-or-not the session had started after at least one flyover had occurred. There is little opportunity to experience annoyance if the flyover noise is not perceived. Also, some of the participants spontaneously mentioned that since taking part in the experiment, they were much more aware of aircraft noise in their home, recreation and work activities. Being in the experiment emphasized aircraft noise and led to greater awareness and possibly potential for aircraft noise annoyance as it occurs in the community. This leads to a possible explanation of a phenomenon we have observed at Seattle-Tacoma International Airport. Our best estimate of noise exposure is that it has improved in the 1973 to present time frame as opposed to the 1967 to 1969 period. However, during the later time frame there appears to be more concern with aircraft noise than during the 1967 to 1969 period. This also could be attributed to increased awareness on the part of members of the community due to greater publicity and interest in environmental matters.

It will be recalled that at the end of the last of the eight 1.5-hour sessions, each participant was asked to estimate the average number of flyovers they had heard each evening. We did not obtain this estimate at the end of each session due to concern that some participants might count the number of events during subsequent sessions. The average number of events for each of the six groups and range of estimates is given in Table XXII. On the average, participants estimated that they heard some 6.7 flyovers per session while they were exposed to 12 flyovers per session. Groups IV and VI provided the highest average estimates with respective means of 8.1 and 7.2 and these two groups experienced 18 flyovers during their last session. The most common average estimate for the eight sessions was 4 which was given by 23% of the participants. No one estimated that they experienced more than 12 flyovers. Six percent of the participants, one each from Groups III, IV

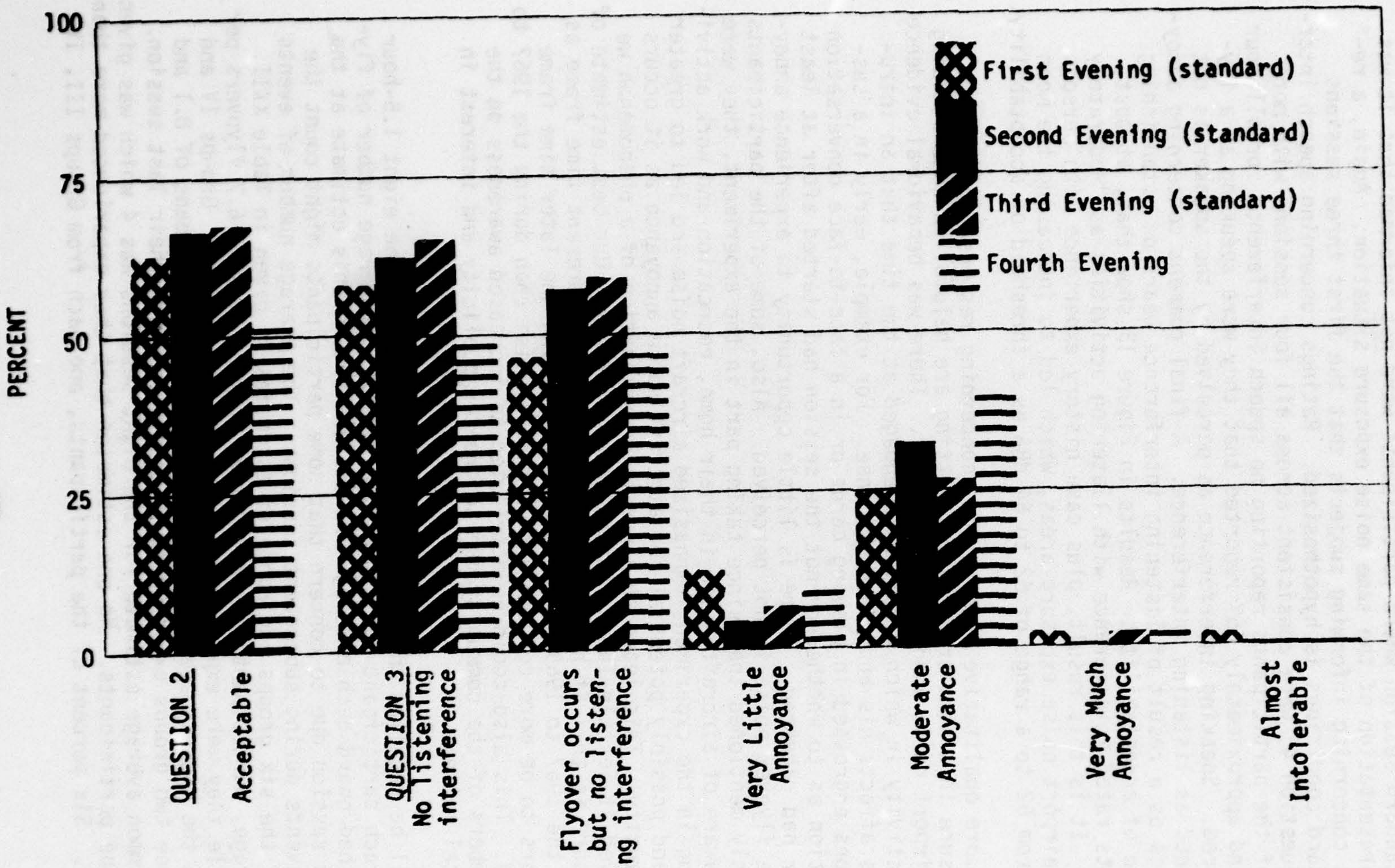


Figure 13. Response to Items 2, 3, and 4 for four Standard conditions (see Session Evaluation Form I, pp. 13-15).

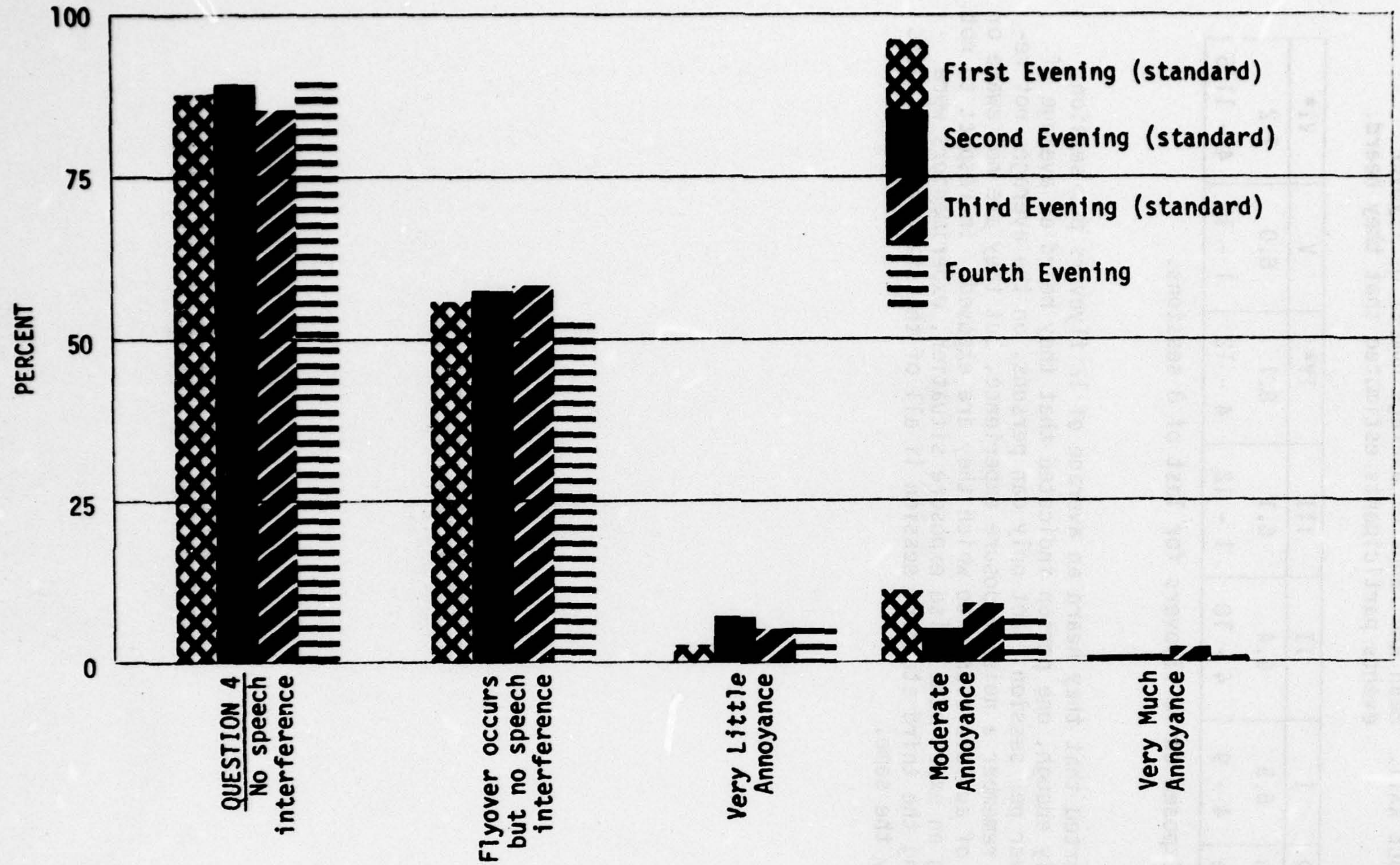


Figure 13 (continued). Response to Items 2, 3, and 4 for four Standard conditions (see Session Evaluation Form I, pp. 13-15).

TABLE XXII. Mean and range of average number of flyover events participants estimated that they heard.

GROUP	I	II	III	IV*	V	VI*
Mean	6.5	6.4	6.1	8.1	6.0	7.2
Range	4 - 9	4 - 10	1 - 12	4 - 12	1 - 12	4 - 11.5

* Exposed to 18 flyovers for last of 8 sessions.

and VI reported that they heard an average of 12 flyovers per session. Surprisingly enough, one person indicated that they heard an average of but 1 flyover per session. Not only can persons, on the average, not recognize or remember a noise exposure experience, but they are not aware of the number of audible events to which they are exposed. In respect to not recognizing an exact same noise exposure situation, experimentors were asked during the third standard session if all of the standard conditions were really the same.

4.0 SUMMARY OF CONCLUSIONS

A number of conclusions are provided in the "3.0 RESULTS" section. Some of them are considered as more significant than others relative to establishing community noise criteria in areas around commercial airports and others are concerned with procedures or methods for obtaining criteria data. Thus, this section emphasizes two sets of conclusions. The first set provides a summary of conclusions that have applied implications relative to commercial airport noise exposure considerations, while the second set deals with conclusions concerning methods and procedures for completing criteria research.

4.1 Application Conclusions

1. The "deep thrust" takeoff procedure results in reduced, listening interference as opposed to the "in route climb" takeoff procedure for the 727-100 and 727-200 aircraft.

2. Noise exposure from a "new" aircraft fleet mix (circa 1980) is clearly more acceptable than that from an "old" aircraft fleet mix (circa 1965). There were three times as many events over the same exposure time period for the "new" fleet mix vs. the "old" fleet mix.

3. Commonly used noise exposure methods such as NEF, L_{eq} and mean peak dBA are level-dependent. Using NEF as an example, for doubling or halving of annoyance in the 25 to 35 NEF range requires some 14 to 15 dB, while for 35 NEF and greater, the best estimate is that 9 to 10 dB results in doubling or halving of annoyance. The implication of this conclusion is that there is a community resistance point at which further noise reductions will result in a minimum reduction in community annoyance response.

4. It is concluded that a difference for noise exposure approaches of 2.5 to 4.0 dB is perceived as a reliable change in noise exposure. Depending on the noise exposure method used, a reduction of 2.5 dB could have a beneficial effect in terms of community noise annoyance response.

5. The predictive capability of a noise exposure method is very much a function of the engineering calculation procedure employed to weight the acoustic energy prior to summing or averaging. In order of predictive capability, dBH demonstrated best predictive capability, $PNdB_T$ was next, and dBA showed the least predictive capability.

6. It is concluded that the mean of the peak levels has greater predictive capability (more representative of community noise annoyance response) than energy summation methods such as NEF and L_{dn} (See Table XV). Mean peak level determinations regardless of the engineering calculation procedure used to weight the acoustic energy are superior to energy summation methods. L_{eq} utilizing a dBA weighting is a relatively poor predictor.

7. There is some evidence that the number of flyover intrusions is not critical in predicting community noise annoyance. However, the addition of 5 log N to mean peak level determinations resulted in an improvement in predictive capability.

8. It is concluded that a mean peak dBA level of 62 to 64 is an acceptable upper limit for noise exposure in residential living quarters around commercial airports. A range of 62-64 dBA for mean peak levels is an upper threshold limit.

4.2 Methods Conclusions

1. A listening interference measure is more sensitive to a reduction in noise exposure than predictions of whether-or-not the reduced exposure condition would be acceptable in subject's "usual living environment."

2. Noise acceptability and listening interference ratings can be influenced by instructions.

3. The activity in which a person is engaged influences their noise annoyance rating.

4. Emphasizing or calling attention to airport noise lowers the threshold of airport noise exposure acceptability.

5. On the average, persons do not perceive the number of flyover events to which they are exposed. There is a strong tendency to underestimate number of flyover intrusions.

6. Persons cannot recognize or remember a noise exposure situation to which they have been exposed.

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APPENDIX A

This appendix provides the descriptions and rank orders for the 109 noise exposure methods evaluated. Rank order is based on the magnitude of the product-moment coefficient of correlation between noise exposure methods and mean magnitude estimation ratings. For example, noise exposure method No. 77 has the highest correlation coefficient and has a RANK of "1".

TABLE A-1. Description and rank order by coefficient of correlation of noise exposure methods examined (Objective 5.)

NO.	DESCRIPTION		RANK	NO.	DESCRIPTION		RANK
1	L_{eq} - dBA	[1]I	94	17	Mean Peak dBA [3](all)	I	58
2	L_{eq} - dBA	[1]0	72	18	Mean Peak dBA [4](Top 6)	I	60
3	L_{eq} - dBH	I	30	19	Mean Peak $PNdB_T$ (all)	I	55
4	L_{eq} - dBH	0	5	20	Mean Peak $PNdB_T$ (Top 6)	I	28
5	L_{eq} - $PNdB_T$	I	77	21	Mean Peak dBH (all)	I	17
6	L_{eq} - $PNdB_T$	0	31	22	Mean Peak dBH (Top 6)	I	3
7	[2]TA > 60 dBA	I	107	23	[5]log Sum Peak dBA	I	54
8	log (No. 7)	I	82	24	log Sum Peak $PNdB_T$	I	20
9	TA > 80 dBA	0	106	25	log Sum Peak dBH	I	8
10	log (No. 9)	0	87	26	[6]Mean dBA_D	I	103
11	TH > 60 dBH	I	93	27	Mean EPNdB	I	92
12	log (No. 11)	I	56	28	Mean dBH_D	I	69
13	TH > 85 dBH	0	70	29	Mean Peak dBH (all)	0	16
14	log (No. 13)	0	99	30	Mean Peak dBH (Top 6)	0	19
15	TH > 80 dBH	0	97	31	[5]log Sum Peak dBH	0	32
16	log (No. 15)	0	83	32	[7]Repeat L_{eq} - dBA	I	101

TABLE A-1 (continued). Description and rank order by coefficient of correlation of noise exposure methods examined (Objective 5.)

NO.	DESCRIPTION		RANK	NO.	DESCRIPTION		RANK
33	[8]Mean Peak dBA + 10 log N	I	51	49	Mean dBA_D + N/6	I	102
34	Mean Peak + N/6	I	56	50	Mean dBA_D + 15 log N	I	91
35	Mean Peak $PNdB_T$ + 10 log N	I	36	51	Mean dBA_D + 5 log N	I	96
36	Mean Peak $PNdB_T$ + N/6	I	52	52	Mean EPNdB + 10 log N	I	81
37	Mean Peak dBH + 10 log N	I	6	53	Mean EPNdB + N/6	I	88
38	Mean Peak dBH + N/6	I	12	54	Mean EPNdB + 15 log N	I	79
39	Mean Peak dBA + 15 log N	I	64	55	Mean EPNdB + 5 log N	I	82
40	Mean Peak $PNdB_T$ + 15 log N	I	50	56	Mean dBH_D + 10 log N	I	46
41	Mean Peak dBH + 15 log N	I	18	57	Mean dBH_D + N/6	I	67
42	Mean Peak dBA + 5 log N	I	48	58	Mean dBH_D + 15 log N	I	47
43	Mean Peak $PNdB_T$ + 5 log N	I	38	59	Mean dBH_D + 5 log N	I	59
44	Mean Peak dBH + 5 log N	I	7	60	Peak dBA_D	I	105
45	[9]Peak dBA Level	I	22	61	Peak EPNdB	I	66
46	Peak $PNdB_T$ Level	I	24	62	Peak dBH_D	I	25
47	Peak dBH Level	I	68	63	Peak dBA_D	0	57
48	Mean dBA_D + 10 log N	I	90	64	Peak EPNdB	0	29

TABLE A-1 (continued). Description and rank order by coefficient of correlation of noise exposure methods examined (Objective 5.)

NO.	DESCRIPTION		RANK
65	Peak dBH_D	0	53
66	Peak dBA Level	0	13
67	Peak $PNdB_T$ Level	0	62
68	Peak dBH Level	0	89
69	N		108
70	log N		109
71	Mean Peak dBA (Top 7)	I	63
72	Mean Peak dBA (Top 6) + 10 log N	I	104
73	Mean Peak dBA (Top 7) + 10 log N	I	84
74	Mean Peak $PNdB_T$ (Top 7)	I	33
75	Mean Peak $PNdB_T$ (Top 6) + 10 log N	I	61
76	Mean Peak $PNdB_T$ (Top 7) + 10 log N	I	65
77	Mean Peak dBH (Top 7)	I	1
78	Mean Peak dBH (Top 6) + 10 log N	I	40

NO.	DESCRIPTION		RANK
79	Mean Peak dBH (Top 7) + 10 log N	I	31
80	log Sum Peak dBH (all) + 10 log N	I	44
81	log Sum dBH (Top 6)	I	14
82	log Sum dBH (Top 6) + 10 log N	I	34
83	log Sum dBH (Top 7)	I	9
84	log Sum dBH (Top 7) + 10 log N	I	35
85	Mean Peak dBH (Top 8)	I	2
86	log Sum dBA (all) + 10 log N	I	85
87	log Sum $PNdB_T$ (all) + 10 log N	I	49
88	Mean Peak dBA (all)	0	43
89	Mean Peak dBA (Top 6)	0	27
90	Mean Peak $PNdB_T$ (all)	0	45
91	Mean Peak $PNdB_T$ (Top 6)	0	4

TABLE A-1(continued). Description and rank order by coefficient of correlation of noise exposure methods examined (Objective 5.)

NO.	DESCRIPTION		RANK	NO.	DESCRIPTION		RANK
92	log Sum dBA_D (Top 6)	I	98	101	log Sum dBA_D (Top 5)	0	75
93	log Sum EPNdB (Top 6)	I	78	102	log Sum dBA_D (Top 6)	0	74
94	log Sum dBH_D (Top 6)	I	23	103	log Sum dBA_D (Top 7)	0	71
95	log Sum dBA_D (Top 7)	I	95	104	log Sum EPNdB (Top 5)	0	41
96	log Sum EPNdB (Top 7)	I	73	105	log Sum EPNdB (Top 6)	0	39
97	log Sum dBH_D (Top 7)	I	21	106	log Sum EPNdB (Top 7)	0	37
98	log Sum dBA_D (Top 5)	I	100	107	log Sum dBH_D (Top 5)	0	15
99	log Sum EPNdB (Top 5)	I	76	108	log Sum dBH_D (Top 6)	0	11
100	log Sum dBH_D (Top 5)	I	26	109	log Sum dBH_D (Top 7)	0	10

[1]"I" means based on indoor measurements; "0" means based on outdoor measurements.

[2]"TA" means time noise is above a particular dBA level;
"TH" means " " " " " " dBH level.

[3]Mean peak based on all flyovers for each condition.

[4]Mean peak based on loudest 6 flyovers.

[5]This is the logarithmic sum of peak levels for all flyovers.

[6]Ten dB down duration corrected according to FAR-36.

[7]This is a reliability test of L_{eq} using a separate 1/3-octave analysis of the flyover signals in real time.

[8]"N" is number of flyovers.

[9]This means peak of only loudest flyover.